APIDOLOGIE – supplementary material

Natural strategies for the control of *Paenibacillus larvae*, causative agent of American foulbrood in honey bees. A review

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Tables

Table I. Essential oils for the *in vitro Paenibacillus larvae* control.

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Acantholippia seriphioides A. Gray	Broth macrodilution	Inhibitory		236 mg/L		(Fuselli et al. 2006a)
	Broth microdilution	Inhibitory		300 mg/L		(Fuselli et al. 2005)
		Inhibitory		213-248 mg/L	248-293 mg/L	(Fuselli et al. 2007)
Achyrocline satureioides Lam.	Agar diffusion	Inhibitory	10 µL			(González and Marioli 2010)
Artemisia absinthium L.	Broth microdilution	Inhibitory		416 mg/L	647 mg/L	(Fuselli et al. 2008a)
Artemisia annua L.	Broth microdilution	Inhibitory		402 mg/L	624 mg/L	(Fuselli et al. 2008a)
Aloysia polystachia Griseb.	Broth microdilution	Inhibitory		700-800 mg/L	900 mg/L	(Fuselli et al. 2008a)
Carapa guianensis Aubl.	Broth microdilution	Inhibitory		25 % (v/v)		(Santos et al. 2012)
Carapa guianensis Aubl. nanoemulsion		Inhibitory		0.39% (v/v)		(de Almeida Vaucher et al. 2015)
Carum carvi L.	Agar diffusion	Inhibitory	5 µL, 10 µL			(Kuzyšinová et al. 2014)
Chamomilla recutita L.	Agar diffusion	Non inhibitory	5 µL, 10 µL			(Kuzyšinová et al. 2014)
Cinnamomum sp.	Agar diffusion	Inhibitory				(Floris et al. 1996)
	Broth macrodilution	Inhibitory			50-100 µg/mL	(Floris et al. 1996)
Cinnamomum aromaticum L.	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		0.015 % (v/v) (strong activity)		(Roussenova 2011)
Cinnamomum camphora (L) J. Presl.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	286.2 ± 27.9 µg/mL	375.0 ± 34.8 µg/mL	(Ansari et al. 2015)
Cinnamomum glandulifera Nees.	Agar dilution	Inhibitory		700 µg/mL		(Alippi et al. 2001)

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Cinnamomum zeylanicum L.	Agar diffusion	Inhibitory	2 mg/mL			(Cecotti et al. 2012)
	Broth macrodilution	Inhibitory		58-83 µg/mL	108-112 µg/mL	(Fuselli et al. 2006b)
		Inhibitory		25-100 mg/L	25-100 mg/L	(Gende et al. 2008a)
		Inhibitory		38-50 µg/mL		(Gende et al. 2008b)
		Inhibitory		25-67 µg/mL		(Gende et al. 2010a)
Cinnamomum zeylanicum + *Thymus vulgaris* L.	Broth macrodilution	Inhibitory		66.6 µg/mL	95.83 µg/mL	(Fuselli et al. 2006b)
Citrus bergamia Risso	Agar diffusion	Inhibitory				(Floris et al. 1996)
Citrus limon L.	Agar diffusion	Inhibitory				(Floris et al. 1996)
	Broth microdilution	Inhibitory		764 mg/L	2293 mg/L	(Fuselli et al. 2008b)
Citrus nobilis Lour	Broth microdilution	Inhibitory		815 mg/L	2447 mg/L	(Fuselli et al. 2008b)
Citrus paradisi L.	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		0.25-0.5 % (v/v) (medium activity)		(Roussenova 2011)
	Broth microdilution	Inhibitory		385 mg/L	770 mg/L	(Fuselli et al. 2008b)
		Inhibitory		336 mg/L	400 mg/L	(Fuselli et al. 2009)
Citrus reticulata var. *Madurensis* Blanco	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		0.12-1.0 % (v/v) (no-activity)		(Roussenova 2011)
Citrus sinensis L.	Agar diffusion	Inhibitory				(Floris et al. 1996)
	Broth microdilution	Inhibitory		840 mg/L	2520 mg/L	(Fuselli et al. 2008b)
		Inhibitory		800 mg/L	933 mg/L	(Fuselli et al. 2009)
		Inhibitory			100-200 µg/mL	(Floris et al. 1996)
Coriandrum sativum L.	Agar dilution	Inhibitory		600-700 µg/mL		(Alippi et al. 2001)
Copaifera officinalis L.	Broth microdilution	Inhibitory		1.56 % (v/v)		(Santos et al. 2012)
Copaifera officinalis L. nanoemulsion		Inhibitory		0.39 % (v/v)		(de Almeida Vaucher et al. 2015)
Cuminum cyminum L.	Agar diffusion	Inhibitory				(Floris et al. 1996)
	Broth macrodilution	Inhibitory			100-200 µg/mL	(Floris et al. 1996)
Cymbopogon citratus Stapf	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		50-100 µL/L		(Alippi 1996)
		Inhibitory		0.015 % (v/v) (strong activity)		(Roussenova 2011)

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Cymbopogon citratus + *Thymus vulgaris* L.	Agar dilution	Inhibitory		25-100 µg/mL		(Alippi et al. 2001)
C. citratus + *T. vulgaris* + *Satureja hortensis* L.+ *Origanum vulgare* L.+ *Ocimum basilicum* L.	Agar dilution	Inhibitory		25-175 µg/mL		(Alippi et al. 2001)
C. citratus + *T. vulgaris* + *O. basilicum*	Agar dilution	Inhibitory		50-350 µg/mL		(Alippi et al. 2001)
Cymbopogon martini Stapf.	Broth microdilution	Inhibitory		1195 mg/L	1208 mg/L	(Fuselli et al. 2010)
Cymbopogon nardus L.	Broth microdilution	Inhibitory		319 mg/L	595 mg/L	(Fuselli et al. 2010)
Daucus carota L.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	412.8 ± 26.0 µg/mL	589.6 ± 48.2 µg/mL	(Ansari et al. 2015)
Eucalyptus cinerea F. Muell	Agar diffusion	Inhibitory	10 µL			(González and Marioli 2010)
Eucalyptus globulosus Labill.	Agar dilution	Inhibitory		>700 µL/L		(Alippi 1996)
	Broth macrodilution	Inhibitory		600-1200 µg/mL		(Gende et al. 2010b)
Eugenia spp.	Agar diffusion	Inhibitory				(Floris et al. 1996)
	Broth macrodilution	Inhibitory			100-200 µg/mL	(Floris et al. 1996)
Foeniculum vulgare Mill	Agar diffusion	Inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
	Broth macrodilution	Inhibitory		250 µg/mL		(Gende et al. 2009b)
Heterothalamus alienus Spreng.	Broth macrodilution	Inhibitory		800-900 mg/L		(Ruffinengo et al. 2006)
		Inhibitory		700-800 mg/L	1,000 mg/L	(Fuselli et al. 2008a)
Hyssopus officinalis L.	Agar diffusion	Inhibitory				(Floris et al. 1996)
Illicium verum Hook.f.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	278.6 ± 21.2 µg/mL	365.0 ± 32.1 µg/mL	(Ansari et al. 2015)
Lavandula sp	Agar dilution	Inhibitory		>700 µL/L		(Alippi 1996)
Lavandula officinalis L.	Broth macrodilution	Inhibitory		350-400 µg/mL		(Gende et al. 2008b)

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Laurus nobilis L.	Agar dilution	Inhibitory		700 µg/mL		(Alippi et al. 2001)
Lepechinia floribunda Benth.	Broth microdilution	Inhibitory		394 mg/L	518 mg/L	(Fuselli et al. 2008a)
Lippia turbinata Griseb	Broth macrodilution	Inhibitory		866 mg/L		(Fuselli et al. 2006a)
Litsea cubeba Pers.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	85.0 ± 7.9 µg/mL	186.0 ± 21.2 µg/mL	(Ansari et al. 2015)
Melaleuca alternifolia Maiden & Betche	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		0.015-0.12 % (v/v) (strong activity)		(Roussenova 2011)
	Broth microdilution	Inhibitory		1095 mg/L	1187 mg/L	(Fuselli et al. 2010)
		Inhibitory		0.18-1.5 % (v/v)		(Santos et al. 2014)
		Inhibitory		331 mg/L	585 mg/L	(Fuselli et al. 2010)
Mentha arvensis L.	Agar diffusion	Inhibitory				(Floris et al. 1996)
		Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory		1000-1800 µg/mL	1600-2000 µg/mL	(Gende et al. 2014)
		Inhibitory	3200 to 0.78 µg/mL	144.7 ± 17.2 µg/mL	248.0 ± 23.4 µg/mL	(Ansari et al. 2015)
Mentha piperita L.	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		600-650 µL/L		(Alippi 1996)
		Inhibitory		0.03-0.06 % (v/v) (strong activity)		(Roussenova 2011)
	Broth macrodilution	Inhibitory		650-700 µg/mL		(Gende et al. 2008b)
Mentha (hybrid)	Broth microdilution	Inhibitory		600-700 µg/mL	1000-1200 µg/mL	(Gende et al. 2014)
Mentha rotundifolia L.	Broth microdilution	Inhibitory		600-1000 µg/mL	1600->2000 µg/mL	(Gende et al. 2014)
Mentha spicata L.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	145.6 ± 15.4 µg/mL	256.0 ± 26.5 µg/mL	(Ansari et al. 2015)
Minthostachys mollis Kunth.	Broth macrodilution	Inhibitory		775 mg/L		(Fuselli et al. 2006a)
Minthostachys verticillata Griseb	Agar diffusion	Inhibitory	10 µL			(González and Marioli 2010)

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Myristica fragrans Gronov.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	285.8 ± 29.2 µg/mL	371.3 ± 29.0 µg/mL	(Ansari et al. 2015)
Ocimum basilicum L.	Agar dilution	Inhibitory		350-450 µg/mL		(Alippi et al. 2001)
		Inhibitory		0.06-0.12 % (v/v) (medium activity)		(Roussenova 2011)
	Agar diffusion	Inhibitory				(Roussenova 2011)
Ocimum tenuiflorum L.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	412.8 ± 26.0 µg/mL	589.6 ± 48.2 µg/mL	(Ansari et al. 2015)
Origanum vulgare L.	Agar diffusion	Non inhibitory	10 µL			(González and Marioli 2010)
		Inhibitory	10 µL			(Roussenova 2011)
		Inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
	Agar dilution	Inhibitory		250-450 µL/L		(Alippi 1996)
		Inhibitory		0,06 % (v/v) (strong activity)		(Roussenova 2011)
Pelargonium graveolens l'Herit	Agar diffusion	Inhibitory				(Floris et al. 1996)
Pelargonium graveolens L.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	495.4 ± 32.9 µg/mL	690.5 ± 75.0 µg/mL	(Ansari et al. 2015)
Pimenta dioica (L.) Merr.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	78.0 ± 8.2 µg/mL	162.0 ± 18.2 µg/mL	(Ansari et al. 2015)
Pimpinella anisum L.	Agar diffusion	Inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
	Broth macrodilution	Inhibitory		300 µg/mL		(Gende et al. 2009b)
Polygonum bistorta L.	Agar diffusion	Inhibitory	2 mg/mL			(Cecotti et al. 2012)

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Rosmarinus officinalis L.	Agar diffusion	Inhibitory				(Floris et al. 1996)
		Non inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
	Agar dilution	Inhibitory		700 µL/L		(Alippi 1996)
	Broth microdilution	Inhibitory		750-1200 µg/mL		(Maggi et al. 2011)
Salvia officinalis L.	Agar diffusion	Inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
Salvia sclarea L.	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
	Agar dilution	Inhibitory		0.06 % (v/v) (strong activity)		(Roussenova 2011)
Satureja hortensis L.	Agar dilution	Inhibitory		200-300 µL/L		(Alippi 1996)
Satureja odora Griseb.	Broth microdilution	Inhibitory		700-800 mg/L	900 mg/L	(Fuselli et al. 2008a)
Schinus molle L.	Broth macrodilution	Inhibitory		666 mg/L		(Fuselli et al. 2006a)
Syzygium aromaticum L.	Agar diffusion	Inhibitory	10 µL			(Roussenova 2011)
		Inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
	Agar dilution	Inhibitory		0.015 % (v/v) (strong activity)		(Roussenova 2011)
Tagetes minuta	Agar diffusion	Inhibitory	10 µL			(González and Marioli 2010)
	Agar dilution	Inhibitory		500-650 µg/mL		(Alippi et al. 2001)
		Inhibitory		700-800 µL/L		(Eguaras et al. 2005)
	Broth macrodilution	Inhibitory		900-1000 mg/L		(Fuselli et al. 2005)
		Inhibitory		833 mg/L		(Fuselli et al. 2006a)
Thymol (component of *Thymus vulgaris*)	Broth macrodilution	Inhibitory		100-133 µg/mL	133 µg/mL	(Fuselli et al. 2006b)

Essential oil	Technique	Activity	Amount tested	MIC[a]	MBC[b]	Reference
Thymus vulgaris	Agar diffusion	Inhibitory				(Floris et al. 1996)
		Inhibitory				(Floris et al. 1996)
		Non inhibitory	10 µl			(González and Marioli 2010)
		Inhibitory	10 µl			(Roussenova 2011)
		Inhibitory	5 µL			(Kuzyšinová et al. 2014)
		Inhibitory	10 µL			(Kuzyšinová et al. 2014)
	Agar dilution	Inhibitory		0.03-0.06 % (v/v) (strong activity)		(Roussenova 2011)
		Inhibitory		100-150 µL/L		(Alippi 1996)
	Broth macrodilution	Inhibitory		191-241 µg/mL	241-291 µg/mL	(Fuselli et al. 2006b)
		Inhibitory			200 µg/mL	(Floris et al. 1996)
Trachyspermum ammi L.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	137.0 ± 12.2 µg/mL	224.8 ± 25.6 µg/mL	(Ansari et al. 2015)
Verbena spp.	Agar diffusion	Inhibitory				(Floris et al. 1996)
	Broth macrodilution	Inhibitory			100-200 µg/mL	(Floris et al. 1996)
Verbena officinalis L.	Broth microdilution	Inhibitory		700-800 mg/L	850 mg/L	(Fuselli et al. 2008a)
Wedelia glauca Ortega	Broth microdilution	Inhibitory		700-800 mg/L	950 mg/L	(Fuselli et al. 2008a)
Zingiber officinale Rosc.	Agar diffusion	Inhibitory	10 µL			(Ansari et al. 2015)
	Broth microdilution	Inhibitory	3200 to 0.78 µg/mL	488.0 ± 28.2 µg/mL	618.2 ± 63.0 µg/mL	(Ansari et al. 2015)

Abbreviations: [a] MIC, Minimal Inhibitory Concentration; [b] MBC, Minimal Bactericidal Concentration.

Table II. Essential oils toxicity assays on *Apis mellifera.*[a]

Essential oil	Technique	Toxicity	Amount tested	Reference
Carapa guaianensis	Spraying procedure	non toxic	25 % (v/v)	(Santos et al. 2012)
Carapa guaianensis nanoemulsion	Complete exposure	non toxic	10 % (v/v)	(de Almeida Vaucher et al. 2015)
	In-vivo against larva	slightly toxic		(de Almeida Vaucher et al. 2015)
Cinamomum sp.	Systemic administration	non toxic	400 µg/mL	(Floris et al. 1996)
Citrus sinensis	Systemic administration	non toxic	400 µg/mL	(Floris et al. 1996)
Cuminum cyminum	Systemic administration	non toxic	400 µg/mL	(Floris et al. 1996)
Copaifera officinalis	Spraying procedure	non toxic	1.56 % (v/v)	(Santos et al. 2012)
Copaifera officinalis nanoemulsion	Complete exposure	non toxic	10 % (v/v)	(de Almeida Vaucher et al. 2015)
	In-vivo against larva	non toxic		(de Almeida Vaucher et al. 2015)
Cymbopogon citratus	Systemic administration	moderately toxic (>2 µg EO/bee)	1, 2, 4, 8, 16 and 32 µg EO/bee	(Albo et al. 2003)
Cymbopogon citratus + T*hymus vulgaris* (20:80, v/v)	Systemic administration	slightly toxic (24h-LD50 = 15.94 µg b.e./bee)	0.19, 0.37, 0.75, 1.50, 3.0 and 6.0 µg b.e./bee	(Albo et al. 2003)
Cymbopogon citratus + *Thymus vulgaris* + *Satureja hortensis* + *Origanum vulgare* + *Ocimum basilicum* (5:11:21:26:37, v/v/v/v/v)	Systemic administration	not determined	1.19, 2.37, 4.75, 9.50, 19.0 and 28.0 µg b.e./bee	(Albo et al. 2003)
Cymbopogon citratus + *Thymus vulgaris* + *Ocimum basilicum* (10:20:70, v/v/v)	Systemic administration	virtually non toxic (24h-LD50 = 122 µg b.e./bee)	0.625, 1.25, 2.5, 5.0, 10.0 and 20.0 µg b.e./bee	(Albo et al. 2003)
Cymbopogon citratus + *Thymus vulgaris* + *Coriandrum sativum* (33,3:33,3:33,3, v/v/v)	Systemic administration	not determined	0.12, 0.25, 0.5, 1, 2 and 4 µg a.c./bee	(Albo et al. 2008)
Cymbopogon citratus + *Thymus vulgaris* (50:50, v/v)	Systemic administration	moderately toxic (24h-LD50 = 16.23 µg b.e/bee)	0.18, 0.37, 0.75, 1.5, 3 and 6 µg a.c./bee	(Albo et al. 2008)

Essential oil	Technique	Toxicity	Amount tested	Reference
Cymbopogoncitratus + *Thymus vulgaris* + *Coriandrum sativum* (0.24, 0.24, 0.24, w/w/w)	*In-vivo* against larva	non toxic		(Albo et al. 2008)
Cynamomum zeylanicum	Systemic administration	virtually non toxic	2000; 4000; 8000 and 16000 µg/mL	(Gende et al. 2009a)
Eucalyptus globulus	Complete exposure	non toxic	2.5, 5, 10 and 20 mL per cage of EO	(Gende et al. 2010b)
Eugenia spp.	Systemic administration	non toxic	400 µg/mL	(Floris et al. 1996)
Melaleuca alternifolia	Spraying procedure	toxic/non toxic the nanoparticles of *M. alternifolia*	6.25 % (w/v)	(Santos et al. 2014)
Origanum vulgare	Systemic administration	moderately toxic (≥ 3 µg EO/bee)	3, 6, 12, 24, 48 and 96 µg EO/bee	(Albo et al. 2003)
Rosmarinus officinalis	Complete exposure	non toxic	2.5, 5, 10 and 20 uL per cage of EO	(Maggi et al. 2011)
Satureja hortensis	Systemic administration	moderately toxic (≥ 5 µg EO/bee)	5, 10, 20, 40, 80 and 160 µg EO/bee	(Albo et al. 2003)
Tagetes minuta	Spraying procedure	non toxic	5 % (w/v)	(Eguaras et al. 2005)
Thymus vulgaris	Systemic administration	non toxic	400 µg/mL	(Floris et al. 1996)
		moderately toxic (> 8 µg EO/bee)	2, 4, 8, 16, 32 and 64 µg EO/bee	(Albo et al. 2003)
Verbena spp.	Systemic administration	non toxic	400 µg/mL	(Floris et al. 1996)

[a] Abbreviations: EO, essential oil; b.e., blends of EO; a.c., active compound.

Table III. Essential oils for the *in vivo* American foulbrood control.

Essential oil	***In vivo* effect**	**Reference**
Cymbopogon citratus	non curative, non preventive; even using candy or syrup	(Albo et al. 2003)
	non curative, non preventive	(Albo et al. 2001)
Cynamomum zeylanicum	curative effect (1000 µg/mL); similar to OTC	(Gende et al. 2009a)
	curative effect (400 mg/kg)	(Floris et al. 1996)
Origanum vulgare	non curative, non preventive; even using candy or syrup	(Albo et al. 2003)
	non curative, non preventive	(Albo et al. 2001)
Satureja hortensis	non curative, non preventive; even using candy or syrup	(Albo et al. 2003)
	non curative, non preventive	(Albo et al. 2001)
Thymus vulgare	non curative, non preventive; even using candy or syrup	(Albo et al. 2003)
	non curative, non preventive	(Albo et al. 2001)

Table IV. Plant extracts for the *in vitro Paenibacillus larvae* control.

Plants	Extract	Technique	Activity	Amount tested	MIC[a]	Reference
Achyrocline satureioides	Water	Agar dilution	Inhibitory			(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
	Hexane	Broth microdilution	Inhibitory		0.060±0.037 mg/mL	(González et al. 2015)
	Benzene	Broth microdilution	Inhibitory		0.131±0.081 mg/mL	(González et al. 2015)
	Ethyl ether	Broth microdilution	Inhibitory		0.773±0.261 mg/mL	(González et al. 2015)
	Ethyl acetate	Broth microdilution	Inhibitory		6.545±2.018 mg/mL	(González et al. 2015)
	Hexane	Agar dilution / broth microdilution			16 - 125 µg/mL	(Sabaté et al. 2012)
Azadirachta indica (Neem)	Water	Agar diffusion	Inhibitory	20, 40 and 60 mg/mL/disc		(Anjum et al. 2015)
Bixa Orellana L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			64 - 256 µg/mL	(Flesar et al. 2010)
Camellia sinensis Kuntze	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			256 µg/mL	(Flesar et al. 2010)
Calendula officinalis	Aq. Ethanol 70% (v/v)	Broth microdilution	Inhibitory		12.76 mg/mL	(Piana et al. 2015)
Capparis spinosa L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			32 µg/mL	(Flesar et al. 2010)
Catha edulis Forssk.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			32 - 64 µg/mL	(Flesar et al. 2010)

Plants	Extract	Technique	Activity	Amount tested	MIC[a]	Reference
Cariniana domestica	Aq. Ethanol 70% (v/v)	Broth microdilution	Non-Inhibitory			(Piana et al. 2015)
	Dichloromethane	Broth microdilution	Non-Inhibitory			(Piana et al. 2015)
	Ethyl acetate	Broth microdilution	Inhibitory		4.06 mg/mL	(Piana et al. 2015)
	n-Butanol	Broth microdilution	Inhibitory		0.98 mg/mL	(Piana et al. 2015)
Chenopodium ambrosioide	Water	Agar dilution	Inhibitory	10000 µg/mL		(González and Marioli 2010)
Curcuma longa L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			64 - 256 µg/mL	(Flesar et al. 2010)
Eucalyptus cinerea	Water	Agar dilution	Inhibitory	10000 µg/mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
Eucalyptus citriodora Hook.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			32 - 64 µg/mL	(Flesar et al. 2010)
Eucalyptus gunnii Hook.F.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			16 - 32 µg/mL	(Flesar et al. 2010)
Flourensia riparia Griseb.	Hexane	Agar diffusion	Inhibitory	100 - 50000 µg/mL		(Reyes et al. 2013)
	Ethyl ether	Agar diffusion / agar dilution	Inhibitory	100 - 50000 µg/mL	250 - 2000 µg/mL	(Reyes et al. 2013)
	Chloroform	Agar diffusion / agar dilution	Inhibitory	100 - 50000 µg/mL	250 - 2000 µg/mL	(Reyes et al. 2013)
Flourensia fiebrigii S.F.Blake	Hexane	Agar diffusion	Inhibitory	100 - 50000 µg/mL		(Reyes et al. 2013)
Flourensia fiebrigii	Ethyl ether	Agar diffusion / agar dilution	Inhibitory	100 - 50000 µg/mL	1250 -5000 µg/mL	(Reyes et al. 2013)
Flourencia tortuosa Griseb.	Hexane	Agar diffusion	Inhibitory	100 - 50000 µg/mL		(Reyes et al. 2013)
	Chloroform	Agar diffusion	Inhibitory	100 - 50000 µg/mL		(Reyes et al. 2013)

Plants	Extract	Technique	Activity	Amount tested	MIC[a]	Reference
Gnaphalium gaudichaudianum DC	Water	Agar dilution	Inhibitory	10000 µg/mL		(González and Marioli 2010)
Humulus lupulus L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			2 - 4 µg/mL	(Flesar et al. 2010)
Hypericum acmosepalum N.Robson	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum canariense L.	Methanol	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum delphicum Boiss. & Orph.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum dolabriforme Vent.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum drummondii Torr. & A.Gray	Methanol	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum heterophyllum Vent.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum hirsutum L.	Methanol	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum maculatum Crantz	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum mutilum L.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
	Methanol	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum myrtifolium Lam.	Dichloromethane	Agar diffusion	Non inhibitory	25 and 50 µg		(Hernández-López et al. 2014)
			Inhibitory	100 µg		(Hernández-López et al. 2014)
Hypericum perforatum L.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum scabrum L.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)
Hypericum tomentosum L.	Dichloromethane	Agar diffusion	Inhibitory	25, 50 and 100 µg		(Hernández-López et al. 2014)

Plants	Extract	Technique	Activity	Amount tested	MIC[a]	Reference
Laurus nobilis	Ethanol	Broth microdilution			208 - 416 µg/mL	(Damiani et al. 2014)
	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			16 - 32 µg/mL	(Flesar et al. 2010)
Lippia turbinata	Water	Agar dilution	Inhibitory	10000 µg/mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
Mangifera indica L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			128 - 256 µg/mL	(Flesar et al. 2010)
Marrubium vulgare L.	Water	Agar dilution	Inhibitory	10000 µg /mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
Melia azedarach L.	Ethanol	Broth macrodilution			5000 µg/mL	{Gende, 2008 #1324}
Minthostachys verticillata	Water	Agar dilution	Inhibitory	10,000 µg /mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
Myrtus communis L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			2 - 8 µg/mL	(Flesar et al. 2010)
Nasturtium officinale	Aq. Ethanol 70% (v/v)	Broth microdilution	Inhibitory		30.51 mg/mL	(Piana et al. 2015)
Olea europaea L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			256 µg/mL	(Flesar et al. 2010)
Origanum vulgare	Water	Agar dilution	Non inhibitory / Inhibitory	10000 µg/mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Non inhibitory / Inhibitory			(González and Marioli 2010)
Punica granatum L.	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			256 µg/mL	(Flesar et al. 2010)
Rosmarinus officinalis	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			16 - 32 µg/mL	(Flesar et al. 2010)

Plants	Extract	Technique	Activity	Amount tested	MIC[a]	Reference
Scutia buxifolia Reiss	Crude extract	Broth microdilution			50 mg/mL	(Boligon et al. 2013)
	Dichloromethane	Broth microdilution			1.56 mg/mL	(Boligon et al. 2013)
	Ethyl acetate	Broth microdilution			6.25 mg/mL	(Boligon et al. 2013)
	n-Butanol	Broth microdilution			25 mg/mL	(Boligon et al. 2013)
Tagetes minuta	Water	Agar dilution	Inhibitory	10000 µg/mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
Thymus vulgaris	Water	Agar dilution	Non inhibitory / Inhibitory	10000 µg /mL		(González and Marioli 2010)
	Water (remaining hydro-distillation)	Agar dilution	Inhibitory			(González and Marioli 2010)
Vitex trifolia	Water	Agar diffusion	Inhibitory	20, 40 and 60 mg/mL/disc		(Anjum et al. 2015)
Zingiber officinale Roscoe	Methanol-dichlorometane (1:1, v/v)	Broth microdilution			32 - 256 µg/mL	(Flesar et al. 2010)

[a] Abbreviations: Aq., aqueous; MIC, Minimal Inhibitory Concentration.

Table V. Plant extracts toxicity assays on *Apis mellifera*.

Plants	Extract	Technique	Toxicity	Amount tested	References
Calendula officinalis	Aq. Ethanol 70% (v/v)	Spraying procedure	33.32% mortality	Data not available	(Piana et al. 2015)
Cariniana domestica	Ethyl acetate	Spraying procedure	73.36% mortality	Data not available	(Piana et al. 2015)
	n-Butanol	Spraying procedure	non toxic	Data not available	(Piana et al. 2015)
Flourensia riparia	Ethyl ether	Complete exposure	non toxic	2; 4; 8; 16; 31.25; 62.5 and 125 mg/mL	(Reyes et al. 2013)
	Chloroform	Complete exposure	non toxic	2; 4; 8; 16; 31.25; 62.5 and 125 mg/mL	(Reyes et al. 2013)
Flourensia fiebrigii	Ethyl ether	Complete exposure	non toxic	2; 4; 8; 16; 31.25; 62.5 and 125 mg/mL	(Reyes et al. 2013)
Humulus lupulus	Methanol-dichlorometane	Complete exposure	non toxic	100 µg [24 h: LD50 > 100 µg/bee]	(Flesar et al. 2010)
Myrtus communis	Methanol-dichlorometane	Complete exposure	non toxic	100 µg [24 h: LD50 > 100 µg/bee]	(Flesar et al. 2010)
Nasturtium officinale	Aq. Ethanol 70% (v/v)	Spraying procedure	non toxic	Data not available	(Piana et al. 2015)
Scutia buxifolia	Crude extract	Spraying procedure	non toxic	50 mg /mL	(Boligon et al. 2013)
	Dichloromethane	Spraying procedure	non toxic	1.56 mg/mL	(Boligon et al. 2013)
	Ethyl acetate	Spraying procedure	non toxic	6.25 mg/mL	(Boligon et al. 2013)
	n-Butanol	Spraying procedure	non toxic	25 mg/mL	(Boligon et al. 2013)

Table VI. Propolis extracts and propolis individual compounds for the *in vitro Paenibacillus larvae* control.

Compound	Propolis extract solvent	*Botanical* / Geographical origin	Technique	Activity	Amount tested	MIC[a]	Reference
9-oxo-10(E),12(Z)-octadecanoic acid		Bulgaria	Agar diffusion	Inhibitory	25 µg		(Bíliková et al. 2013)
			Broth microdilution			1,000 µg/mL	(Bíliková et al. 2013)
Benzyl ferulate		Bulgaria	Agar diffusion	Inhibitory	25 µg		(Bíliková et al. 2013)
			Broth microdilution	Inhibitory		500 µg/mL	(Bíliková et al. 2013)
Caffeate mixture		Bulgaria	Agar diffusion	Inhibitory	25 µg		(Bíliková et al. 2013)
			Broth microdilution	Inhibitory		125 µg/mL	(Bíliková et al. 2013)
Pentenyl ferulate		Bulgaria	Agar diffusion	Inhibitory	25 µg		(Bíliková et al. 2013)
			Broth microdilution	Inhibitory		500 µg/mL	(Bíliková et al. 2013)
Pinobanksin-3-O-acetate		Bulgaria	Agar diffusion	Inhibitory	25 µg		(Bíliková et al. 2013)
			Broth microdilution	Inhibitory		125 µg/mL	(Bíliková et al. 2013)
Pinocembrin		Bulgaria	Agar diffusion	Inhibitory	25 µg		(Bíliková et al. 2013)
			Broth microdilution	Inhibitory		62.5 µg/mL	(Bíliková et al. 2013)
–	Ethanol	Bulgaria	Agar diffusion	Inhibitory	100 µg, 50 µg, 25 µg and 10 µg		(Bíliková et al. 2013)
–	Petrol ether		Agar diffusion	Inhibitory	100 µg, 50 µg, 25 µg and 10 µg		(Bíliková et al. 2013)
–	Ethylacetate		Agar diffusion	Inhibitory	100 µg, 50 µg, 25 µg and 10 µg		(Bíliková et al. 2013)

Compound	Propolis extract solvent	*Botanical* / Geographical origin	Technique	Activity	Amount tested	MIC[a]	Reference
–	Ethanol	*Populus* spp / USA	Agar diffusion	Inhibitory	14.3 mg and 15.7 mg		(Bastos et al. 2008)
–	Ethanol	Aspen,CO/USA	Broth microdilution	Inhibitory	8, 10, 20, 30, 50, 60, 75, 100, 125, or 175 µg/mL	47.1 ± 2.4 µg/mL	(Wilson et al. 2015)
–		Beaumont, TX/USA	Broth microdilution	Inhibitory		46.9 ± 2.9 µg/mL	(Wilson et al. 2015)
–		Fallon, NV/USA	Broth microdilution	Inhibitory		41.6 ± 0.5 µg/mL	(Wilson et al. 2015)
–		Jamestown, ND/USA	Broth microdilution	Inhibitory		81.0 ± 2.5 µg/mL	(Wilson et al. 2015)
–		Lincoln, NE/USA	Broth microdilution	Inhibitory		70.6 ± 2.7 µg/mL	(Wilson et al. 2015)
–		Tucson, AZ/USA	Broth microdilution	Inhibitory		78.4 ± 3.9 µg/mL	(Wilson et al. 2015)
–		Vacaville, CA/USA	Broth microdilution	Inhibitory		74.1 ± 4.7 µg/mL	(Wilson et al. 2015)
–	Ethanol	*Vernonia polyanthes* and *Baccharis dracunculifolia* / Brazil	Agar diffusion	Inhibitory	7.05 mg, 7.3 mg, 8.6 mg, 9.1 mg , 10.4 mg and 12.2 mg		(Bastos et al. 2008)
–	Ethanol	Romania	Agar diffusion	Inhibitory	10 mg/mL		(Mihai et al. 2012)
–	Dicloromethane	Thailand	Agar diffusion	Non inhibitory	100 mg/mL		(Boonsai et al. 2014)
			Broth microdilution	Inhibitory	100 mg/mL	> 500 mg/mL	(Boonsai et al. 2014)
–	Hexane		Agar diffusion	Non inhibitory	100 mg/mL		(Boonsai et al. 2014)
			Broth microdilution	Non inhibitory	100 mg/mL	> 500 mg/mL	(Boonsai et al. 2014)

Compound	Propolis extract solvent	*Botanical* / Geographical origin	Technique	Activity	Amount tested	MIC[a]	Reference
–	Methanol		Agar diffusion	Inhibitory	100 mg/mL		(Boonsai et al. 2014)
			Broth microdilution	Non inhibitory	100 mg/mL	6.25 µg/mL	(Boonsai et al. 2014)
–	Ethanol	Uruguay	Agar diffusion	Inhibitory	100 % (v/v); 10 % (v/v) and 1 % (v/v)		(Antúnez et al. 2008)
			Broth macrodilution	Inhibitory	100 % (v/v); 10 % (v/v) and 1 % (v/v)	0.32-0.56 % (v/v)	(Antúnez et al. 2008)
–	Ethanol	Yugoslavia	Agar diffusion	Inhibitory	10 % (v/v) and 5 % (v/v)		(Mlagan and Sulimanovic 1982)

[a] Abbreviations: Aq., aqueous; MIC, Minimal Inhibitory Concentration.

Table VII. Toxicity assays of propolis extracts on *Apis mellifera*.

Geographical origin	Propolis extract solvent	Technique	Toxicity	Amount tested	Reference
China	Ehtanol	Systemic administration	toxic (≥ 0.5 %, w/v) (LC50 = 15.047)	0.025, 0.05, 0.1, 0.5 and 2.1% (w/v)	(Kamel et al. 2013)
Egypt	Ethanol	Systemic administration	toxic (≥ 0.5 %, w/v) (LC50 = 8.223)	0.025, 0.05, 0.1, 0.5 and 2.1% (w/v)	(Kamel et al. 2013)
Uruguay	Ethanol	Systemic administration	non toxic	3-50% (w/v)	(Antúnez et al. 2008)

Table VIII. Propolis extracts for the *in vivo* American foulbrood control.

Geographical origin	Extract	Technique	*In vivo* effect	Reference
China	Ethanol	Systemic administration	Non curative	(Kamel et al. 2013)
Egypt	Ethanol	Systemic administration	Curative effect (0.05 %, w/v)	(Kamel et al. 2013)
			Non curative	(Kamel et al. 2013)
Uruguay	Ethanol	Spraying procedure and by feeding	Decrease in the number of spores (6 %, v/v)	(Antúnez et al. 2008)
USA	Ethanol	Systemic administration	Non curative (500 µg/mL)	(Lindenfelser 1968)
		Spraying procedure	Non curative (500 µg/mL)	(Lindenfelser 1968)

Table IX. Royal jelly for the *in vitro Paenibacillus larvae* control.

Compound	Technique	Activity	Amount tested	Reference
Royalisin	Agar diffusion	Inhibitory	5.4 µg/mL	(Bíliková et al. 2001)
	Bacterial growth-inhibition assay on polyacrilamide gel	Inhibitory	10 µL	(Bachanová et al. 2002)
Royal jelly (Australia)	Coincubation	Inhibitory against vegetative cells of *P. larvae* after 5 min (not spores)	2 mL	(Hornitzky 1998)
Apalbumin2a	Coincubation	Inhibitory against vegetative cells of *P. larvae*	1.86×10^{-4} M	(Bíliková et al. 2009)

Table X. Non conventional natural molecules for the *in vitro Paenibacillus larvae* control.

Molecule[a]	Technique	Activity	Amount tested	MIC[c]	Reference
(2S)-8-(3”-Methylbut-2”-enyl)-7,3´,4´-trihydroxyflavanone *(Flourensia fiebrigii)*[b]	Agar dilution	Inhibitory	100- 2500 µg/mL	500 µg/disc	(Reyes et al. 2013)
1,8-Cineol	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
11,14,17-Eicosatrienoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
11,14-Ecosadienoic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
		Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
11-Transeicosaenoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
13,16,19-Docosatrienoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
13,16-Docosadienoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
4,7,10,13,16,19-Docosahexenoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
6-methoxytremetone (*Flourensia fiebrigii*)[b]	Agar dilution	Non Inhibitory	100- 2,500 µg/mL	>1000 µg/disc	(Reyes et al. 2013)
5,3_-dihydroxyisobavachin-7-O-methyl etherand (*Flourensia fiebrigii*)[b]	Agar dilution	Non Inhibitory	100- 2,500 µg/mL	>1000 µg/disc	(Reyes et al. 2013)
7,10,13,16-Docosatetraenoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
7-Epiclusianone (*Hypericum canariense*)[b]	Broth macrodilution (vegetative cells)	Inhibitory	0.09-90 µg/mL	1,78 µM	(Hernández-López et al. 2014)
8-Prenyldihydroisorhamnetin (*Flourensia riparia*)[b]	Agar dilution	Inhibitory	100- 2500 µg/mL	500 µg/disc	(Reyes et al. 2013)
8-Prenyleryodictiol (*Flourensia fiebrigii*)[b]	Agar dilution	Inhibitory	100- 2500 µg/mL	500-1,000 µg/disc	(Reyes et al. 2013)
8-Prenylnaringenin (*Flourensia riparia*)[b]	Agar dilution	Non Inhibitory	100- 2500 µg/mL	-	(Reyes et al. 2013)

Molecule[a]	Technique	Activity	Amount tested	MIC[c]	Reference
Albaspidin AA (*Hypericum drummondii*)[b]	Broth macrodilution (vegetative cells)	Inhibitory	0.09-90 µg/mL	220 µM	(Hernández-López et al. 2014)
Arachidonic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Berberin chlotide	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Brassidic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
		Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Caffeic ac.	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Capric ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Caproic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
n-Caproic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Caprylic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Capsaicin	Broth microdilution	Inhibitory	1-128 µg/mL	32 µg/disc	(Flesar et al. 2010)
Carabrone (*Flourensia riparia*)[a]	Agar dilution	Non Inhibitory	100- 2500 µg/mL	-	(Reyes et al. 2013)
Catechin	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Chelidonic ac.	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Chamones I (*Clusia grandiflora*)[b]	Agar diffusion	inhibition (5 µg)	Data not available	-	(Lokvam et al. 2000)
Male and female (*Clusia grandiflora*)[b]	Agar diffusion	Inhibitory (10 µg)	Data not available	-	(Lokvam and Braddock 1999)
Curcumin	Broth microdilution	Inhibitory	1-128 µg/mL	32-64 µg/disc	(Flesar et al. 2010)
Drummondin E (*Hypericum drummondii*)[b]	Broth macrodilution (vegetative cells)	Inhibitory	0.09-90 µg/mL	190 µM	(Flesar et al. 2010)
Elaidic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Ellagic ac.	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Epigallocatechin	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Erucic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Eugenol	Broth microdilution	Mildly inhibitory	1-128 µg/mL	64-128 µg/disc	(Flesar et al. 2010)
Exiguaflavanone K (*Flourensia riparia*)[b]	Agar dilution	Inhibitory	100- 2500 µg/mL	625 µg/disc	(Reyes et al. 2013)

Molecule[a]	Technique	Activity	Amount tested	MIC[c]	Reference
Glepidotin B (*Flourensia riparia*)[b]	Agar dilution	Non Inhibitory	100- 2500 µg/mL	-	(Reyes et al. 2013)
Glycerol monolaurate	Broth macrodilution	Inhibitory	500 - 3.9 µg/mL	62.6 µg/mL	(Lopes et al. 2016)
Glycerol monolaurate nanocapsules	Broth macrodilution	Inhibitory	500 - 3.9 µg/mL	142.8 µg/mL	(Lopes et al. 2016)
Harmane	Broth microdilution	Inhibitory	1-128 µg/mL	32-64 µg/disc	(Flesar et al. 2010)
Heptadecanoic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Hesperetin	Broth microdilution	Non inhibitory	1-128 µg/mL	128 µg/disc	(Flesar et al. 2010)
Homo-γ-Linolenic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Hyperforin (*Hypericum perforatum*)[b]	Broth macrodilution (vegetative cells)	Inhibitory	0.09-90 µg/mL	0,168 µM	(Hernández-López et al. 2014)
	Broth macrodilution (spores)	Inhibitory	10 and 100 µg/mL	4.40 and 4.80 CFU/mL, respectively	(Hernández-López et al. 2014)
Isoalantolactone (*Flourensia riparia*)[b]	Agar dilution	Non Inhibitory	100- 2500 µg/mL	-	(Reyes et al. 2013)
Lauric ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Linoelaidic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Linoleic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Linolelaidic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Linolenic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
γ-Linolenic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Myristic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Myristoleic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Naringenin	Broth microdilution	Inhibitory	1-128 µg/mL	63 µg/disc	(Flesar et al. 2010)

Molecule[a]	Technique	Activity	Amount tested	MIC[c]	Reference
Nemorosone II (*Flourensia riparia*)[b]	Agar diffusion	Inhibitory (5 µg)	Data not available	-	(Lokvam et al. 2000)
Nonanoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Nordihydroguaiaretic ac.	Broth microdilution	Inhibitory	1-128 µg/mL	32 µg/disc	(Flesar et al. 2010)
Oleic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
		Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Palmitelaidic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Palmitic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
		Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Palmitoleic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Pelargonic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Pentadecanoic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Petroselaidic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg		(Feldlaufer et al. 1993b)
Petroselinic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Piperine	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Pyrogallol	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Quercetin dihydrate	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Quininin hydrochloride	Broth microdilution	Inhibitory	1-128 µg/mL	62 µg/disc	(Flesar et al. 2010)
Resveratrol	Broth microdilution	Inhibitory	1-128 µg/mL	64 µg/disc	(Flesar et al. 2010)
Ricinelaidic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Ricinoleic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Sanguinarine	Broth microdilution	Inhibitory	1-128 µg/mL	4 µg/disc	(Flesar et al. 2010)
Scariosin (*Flourensia riparia*)[b]	Agar dilution	Non Inhibitory	100- 2500 µg/mL	-	(Reyes et al. 2013)
Scopoletin (*Flourensia riparia*)[b]	Agar dilution	Non Inhibitory	100- 2500 µg/mL	-	(Reyes et al. 2013)

Molecule[a]	Technique	Activity	Amount tested	MIC[c]	Reference
Stearic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
		Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Hornitzky 2003)
Terpinen-4-ol	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
L-Tenuazonic ac.	Agar diffusion	Inhibitory	100 µg	0.916 µg/disc	(Gallardo et al. 2004)
	Agar dilution	Inhibitory	100 µg	32 µg/disc	(Gallardo et al. 2004)
Thymol	Broth microdilution	Non inhibitory	1-128 µg/mL	64-128 µg/disc	(Flesar et al. 2010)
Thymoquinone	Broth microdilution	Inhibitory	1-128 µg/mL	8-16 µg/disc	(Flesar et al. 2010)
Tomatin	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Trans-2-hexenal	Broth microdilution	Inhibitory	1-128 µg/mL	32 µg/disc	(Flesar et al. 2010)
Trans-Cinnamic ac.	Broth microdilution	Non inhibitory	1-128 µg/mL	> 128 µg/disc	(Flesar et al. 2010)
Trans-Vaccenic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)
Tridecanoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Uliginosin A (*Hypericum mutilum*)[b]	Broth macrodilution (vegetative cells)	Inhibitory	0.09-90 µg/mL	180 µM	(Hernández-López et al. 2014)
Uliginosin B (*Hypericum mutilum*)[b]	Broth macrodilution (vegetative cells)	Inhibitory	0.09-90 µg/mL	20 µM	(Hernández-López et al. 2014)
Undecanoic ac.	Agar diffusion	Inhibitory (25 and 250 µg)	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b; Hornitzky 2003)
Vaccenic ac.	Agar diffusion	Non inhibitory	0.25, 2.5, 25 and 250 µg	-	(Feldlaufer et al. 1993b)

[a] Abbreviation: ac., acid. [b] Plant species from which the molecule comes from. [c] MIC, Minimal Inhibitory Concentration.

Table XI. Toxicity assays of non conventional molecules on *Apis mellifera*.

Molecule	**Technique**	**Toxicity**	**Amount tested**	**Reference**
Capsaicin	Systemic administration	LD50>100 µg/bee	Data not available	(Flesar et al. 2010)
Glycerol monolaurate	Spraying procedure	Higly toxic	1 and 2-fold MIC	(Lopes et al. 2016)
Glycerol monolaurate nanocapsules	Spraying procedure	Non toxic	1 and 2-fold MIC	(Lopes et al. 2016)
trans-2-Hexenal	Systemic administration	Non toxic (>200 µg/bee)	Data not available	(Flesar et al. 2010)
Nordihydroguaiaretic ac.	Systemic administration	LD50>200 µg/bee	Data not available	(Flesar et al. 2010)
Sanguinarina	Systemic administration	Slightly toxic (LD50=153 µg/bee)	Data not available	(Flesar et al. 2010)
Thymoquinone	Systemic administration	Non toxic (>100 µg/bee)	Data not available	(Flesar et al. 2010)

Table XII. Bacteria and bacteriocins for the *in vitro Paenibacillus larvae* control.[a]

Bacteria / Bacteriocin	Source	Technique	Activity	Amount tested	Reference
Acinetobacter calcoaceticus	First instar *A. mellifera* larvae	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2006)
Acinetobacter sp.	*A. mellifera* subsp. carnica, mellifera, and ligustica larvae, collected 3–12h post-hatching	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2005)
Acinetobacter sp. (2 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Non inhibitory / inhibitory	20 µL	(Evans and Armstrong 2006)
Antimicrobial factor LBM 5006	*Bacillus amyloliquefaciens* (supernatant protein purification)	Agar diffusion	Data not available	20 µL	(Benitez et al. 2012)
		Broth macrodilution	An approximately 2 log10 reduction	1600 AU/mL	(Benitez et al. 2012)
		Broth microdilution	Inhibitory 800 AU/mL	3200-0 AU/mL	(Benitez et al. 2012)
Bacillus cereus (30 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Mildly inhibitory / Non inhibitory	20 µL	(Evans and Armstrong 2006)
Bacillus cereus (5 strains)	Brood combs/honey	Perpendicular streak	Inhibitory	Data not available	(Alippi and Reynaldi 2006)
Bacillus cereus (CP001186) - *Acj 209*	Worker bees gut	Agar diffusion	Inhibitory	100 µL	(Yoshiyama and Kimura 2009)
Bacillus cereus (CP001186) - *Acj 219*	Whole larvae	Agar diffusion	Inhibitory	100 µL	(Yoshiyama and Kimura 2009)
Bacillus circulans	First instar *A. mellifera* larvae	Agar diffusion	Non inhibitory	20 µL	(Evans and Armstrong 2006)
Bacillus circulans (2 strains)	Brood combs/honey	Perpendicular streak	Non inhibitory	Data not available	(Alippi and Reynaldi 2006)
Bacillus flexus (4 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Non inhibitory	20 µL	(Evans and Armstrong 2006)
Bacillus fusiformis	*A. mellifera* subsp. carnica, mellifera, and ligustica larvae, collected 3–12h post-hatching	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2005)

Bacteria / Bacteriocin	**Source**	**Technique**	**Activity**	**Amount tested**	**Reference**
Bacillus fusiformis (4 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2006)
Bacillus licheniformis (2 strains)	Brood combs/honey	Perpendicular streak	Inhibitory	Data not available	(Alippi and Reynaldi 2006)
Bacillus megaterium (3 strains)	Brood combs/honey	Perpendicular streak	Inhibitory	Data not available	(Alippi and Reynaldi 2006)
Bacillus mycoides	First instar *A. mellifera* larvae	Agar diffusion	Non inhibitory	20 µL	(Evans and Armstrong 2006)
Bacillus niabensis	First instar *A. mellifera* larvae	Agar diffusion	Non inhibitory	20 µL	(Evans and Armstrong 2006)
Bacillus polymachus T515^{T}	Forest topsoil	Agar diffusion	Inhibitory	15 µL	(Nguyen and Kim 2015a)
Bacillus pumilus	Brood combs/honey	Perpendicular streak	Inhibitory	Data not available	(Alippi and Reynaldi 2006)
Bacillus sp. (8 strains)	Bee gut	Agar diffusion	Non inhibitory	CFS: 33 µL Surfactin: 23 µL	(Sabaté et al. 2009)
Bacillus sp. (4 strains) and *B. subtilis* (3 strains)	Honey	Agar diffusion	Non inhibitory	CFS: 33 µL Surfactin: 23 µL	(Sabaté et al. 2009)
Bacillus subtilis (4 strains)	Brood combs/honey	Perpendicular streak	Inhibitory	Data not available	(Alippi and Reynaldi 2006)
Bacillus subtilis (AB201120)-Acj 214 and Bacillus subtilis subsp. (Z99104)-Acj 115	Worker bees gut	Agar diffusion	Inhibitory	100 µL	(Yoshiyama and Kimura 2009)
Bifidobacterium asteroides (3 strains)	Honey stomachs of honey bees	Agar diffusion	Inhibitory	10^{8} UFC/mL	(Forsgren et al. 2010)
Bifidobacterium coryneforme (Bma6)	Honey stomachs of honey bees	Agar diffusion	Inhibitory	10^{6} UFC/mL	(Forsgren et al. 2010)
Brevibacillus brevis	First instar *A. mellifera* larvae	Agar diffusion	Mildly inhibitory	20 µL	(Evans and Armstrong 2006)

Bacteria / Bacteriocin	**Source**	**Technique**	**Activity**	**Amount tested**	**Reference**
Brevibacillus centrosporus (2 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Non inhibitory	20 µL	(Evans and Armstrong 2006)
Brevibacillus formosus (3 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2006)
Brevibacillus laterosporus (4 strains)	Brood combs/honey	Perpendicular streak	Inhibitory	Data not available	(Alippi and Reynaldi 2006)
Enterococcus sp. (16 isolates)	Fermented feeds and foods	Agar diffusion	Mildly inhibitory	100 µL	(Jaouani et al. 2014)
Enterococcus sp (28 isolates)	Fermented feeds and foods	Agar diffusion	strongly inhibitory	100 µL	(Jaouani et al. 2014)
Enterococcus sp (22 isolates)	Fermented feeds and foods	Agar diffusion	Non inhibitory	100 µL	(Jaouani et al. 2014)
Enterococcus faecium SM21	Gut of worker *A. mellifera Ligústica*	Agar diffusion (Cell Free Supernatant)	Non inhibitory	25 µL	(Audisio et al. 2011)
Enterococcus thailandicus 102	Fermented feeds and foods	Agar diffusion	Inhibitory	20 µL	(Yoshiyama et al. 2013)
Entomocin 110	*Bacillus thuringiensis* subsp. Entomocidus HD110 (supernatant protein purification)	Agar diffusion	Inhibitory	Data not available	(Cherif et al. 2008)
Escherichia coli (CU928164) - Acj 105	Worker bees gut	Agar diffusion	Inhibitory	100 µL	(Yoshiyama and Kimura 2009)
Lactobacillus acidophilus CRL1647	Gut of worker *A. mellifera Ligústica*	Agar diffusion (Cell Free Supernatant)	Inhibitory	25 µL	(Audisio et al. 2011)
Lactobacillus crispatus IG9	Gut of worker *A. mellifera Ligústica*	Agar diffusion (Cell Free Supernatant)	Inhibitory	25 µL	(Audisio et al. 2011)
Lactobacillus curvatus (2 isolates)	Fermented feeds and foods	Agar diffusion	Inhibitory	20 µL	(Yoshiyama et al. 2013)
Lactobacillus jonsonii (2 isolates)	Gut of worker *A. mellifera Ligústica*	Agar diffusion (Cell Free Supernatant)	Inhibitory	25 µL	(Audisio et al. 2011)
Lactobacillus kunkeei (4 isolates)	Honey stomachs of honey bees	Agar diffusion	Inhibitory	10^7 UFC/mL	(Forsgren et al. 2010)
Lactobacillus spp. (2 isolates)	Honey stomachs of honey bees	Agar diffusion	Inhibitory	10^6 UFC/mL	(Forsgren et al. 2010)

Bacteria / Bacteriocin	Source	Technique	Activity	Amount tested	Reference
Lactobacillus spp. (Hma8)	Honey stomachs of honey bees	Agar diffusion	Inhibitory	10^7 UFC/mL	(Forsgren et al. 2010)
Lactobacillus spp. (Hon2)	Honey stomachs of honey bees	Agar diffusion	Inhibitory	10^6 UFC/mL	(Forsgren et al. 2010)
Paenibacillus alvei	Brood combs/honey	Perpendicular streak	Non inhibitory	Data not available	(Alippi and Reynaldi 2006)
Paenibacillus amynolyticus	Brood combs/honey	Perpendicular streak	Non inhibitory	Data not available	(Alippi and Reynaldi 2006)
Paenibacillus azotofixans	Brood combs/honey	Perpendicular streak	Non inhibitory	Data not available	(Alippi and Reynaldi 2006)
Paenibacillus polymyxa	Brood combs/honey	Perpendicular streak	Non inhibitory	Data not available	(Alippi and Reynaldi 2006)
Paenibacillus thiaminolyticus	Brood combs/honey	Perpendicular streak	Non inhibitory	Data not available	(Alippi and Reynaldi 2006)
Providencia alcalifaciens (AY994312)-Acj 108	Worker bees gut	Agar diffusion	Inhibitory	100 µL	(Yoshiyama and Kimura 2009)
Sphingomonas melonis (AB334774)-Acj 111	Worker bees gut	Agar diffusion	Inhibitory	100 µL	(Yoshiyama and Kimura 2009)
Stenotrophomonas maltophilia	*A. mellifera* subsp. carnica, mellifera, and ligustica larvae, collected 3–12h post-hatching	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2005)
Stenotrophomonas maltophilia (10 isolates)	First instar *A. mellifera* larvae	Agar diffusion	Inhibitory	20 µL	(Evans and Armstrong 2006)
Streptomyces polymachus $T258^T$	Forest soil	Agar diffusion	Inhibitory	15 µL	(Nguyen and Kim 2015b)
Weissella cibaria (3 isolates)	Fermented feeds and foods	Agar diffusion	Inhibitory	20 µL	(Yoshiyama et al. 2013)
Weissella paramesenteroides (2 isolates)	Fermented feeds and foods	Agar diffusion	Inhibitory	20 µL	(Yoshiyama et al. 2013)
Weissella viridescens F13	Fermented feeds and foods	Agar diffusion	Inhibitory	20 µL	(Yoshiyama et al. 2013)

[a] Abbreviations: CFS, cell free supernatant; AU, Activity Units.