EFFICACY OF HERBAL ESSENTIAL OILS AS INSECTICIDES AGAINST THE HOUSEFLY, *MUSCA DOMESTICA* L.

Jirisuda Sinthusiri and Mayura Soonwera

Entomology and Environment Program, Faculty of Agricultural Technology
King Mongkut's Institute of Technology Ladkrabang, Lat Krabang, Bangkok, Thailand

Abstract. The insecticidal effects of 20 essential oils derived from herbs, were tested against the housefly species *Musca domestica* L. using a susceptibility test. Each was applied in ethyl alcohol at concentrations of 1, 5 and 10% (v/v). Ten percent concentrations of *Cymbopogon citratus* (lemongrass), *Mentha piperita* (peppermint) and *Lavandula angustifolia* (lavender) oils were the most effective, showing 100% knockdown at 30 and 60 minutes. The KT_{50} values for *C. citratus, M. piperita* and *L. angustifolia* were 5.14, 5.36 and 8.23 minutes, respectively. These essential oils caused 100% mortality among houseflies 24 hours after exposure. The LC_{50} values for *C. citratus*, *M. piperita* and *L. angustifolia* were 2.22, 2.62 and 3.26 minutes, respectively. This study reveals lemongrass, peppermint and lavender essential oils have the potential to control housefly populations and should be further studied for field applications.

Keywords: essential oil, insecticidal activity, housefly, *Musca domestica* L.

INTRODUCTION

The housefly, *Musca domestica* L. (Diptera: Muscidae) is a gray insect, 6-9 mm in length, with four dark stripes running lengthwise on the thoracic dorsum (Harwood and James, 1979). It is a common pest in Thailand. It feeds on and breeds in decaying matter, human waste and food, and is considered a mechanical vector for pathogens (bacteria, protozoa and viruses) to humans and livestock (Olsen *et al*, 2001; Sangmaneedet *et al*, 2005). These pathogens may cause food poisoning, diarrhea, cholera, typhoid, paratyphoid, shigellosis, and anthrax (Banjo *et al*, 2005; Fasanella *et al*, 2005; Yap *et al*, 2008). These vectors may also carry eggs from worm parasites (Wattanachai *et al*, 1996; Ugbogu *et al*, 2006). Myiases among humans has also been reported (Dogra and Mahajan, 2010).

Conventional methods for housefly control include chemical insecticides. Increasing resistance among houseflies has been reported against insecticides, organophosphates, carbamates, synthetic pyrethroids and spinosads (Shono and Scott, 2003; Srinivasan *et al*, 2008). These insecticides may have toxic side effects to humans and non-target organisms (Scott *et al*, 2000). Botanical insecticides are becoming a more popular alternative to chemical insecticides. Essential oils

Correspondence: Jirisuda Sinthusiri, Entomology and Environment Program, Plant Production Technology Section, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Chalong Krung Road, Lat Krabang, Bangkok 10520, Thailand.
Tel: +66 (0) 81 7616265
E-mail: jiri_ja@yahoo.com

from plants reported to have insecticidal effects against adult houseflies include *Minthostachys verticillata, Hedeoma multiflora, Citrus sinensis, Citrus aurantium, Eucalyptus cinerea* and *Artemisia annua* with LC_{50} values of 0.5, 1.3, 3.9, 4.8, 5.5 and 6.5 mg/fly at 30 minutes, respectively (Palacios *et al*, 2009a, b). The essential oil of *Pogostemon cablin* had an LD_{50} value of 3   g/ cm^2 after topical application and *Mentha pulegium* oil had an LD_{50} value of 4.7   g/cm^2 (Pavela, 2008). Essential oils have been shown to be relatively non-toxic to fish, birds and mammals and easily biodegrade in the environment (Stroh *et al*, 1998; Kumar *et al*, 2012b). Some essential oils or their volatile constituents have been used to prevent and treat illness due to perceived antibacterial, antiviral, antioxidant and antidiabetic properties (Edris, 2007). Essential oils have been used in sensitive areas, such as homes, schools, restaurants, and hospitals (Batish *et al*, 2008; Palacios *et al*, 2009b). We determined to study the effect of essential oils from herbal plants to control houseflies.

MATERIALS AND METHODS

Rearing of *M. domestica* colony

Adult houseflies were collected from Hua Takae Market, Lat Krabang, Thailand and reared in gauzier cotton cages (30x30x30 cm^3) at room temperature (32-35ºC) at the Laboratory of Entomology and Environment, Plant Production Technology Section, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand. They were fed with 10% syrup and 10% milk soaked in cotton wool. Three hundred grams of Mackerel fish were placed in a plastic tray (18x25x9 cm^3) lined with sterile coconut husks for the houseflies to feed and lay their eggs in. Newly emerged adults were used for the study.

Plant materials

We studied 20 essential oils (Table 1) extracted by steam hydrodistillation and prepared as 1, 5, and 10% solutions in ethyl alcohol (v/v). All formulations were kept at room temperature until tested.

Insecticide susceptibility test

We used a susceptibility test kit and followed WHO susceptibility test guidelines (WHO, 2006). The flies were exposed to essential oil treated filter paper for one hour in a tube then transfered to another tube where knockdown rates were recorded at 5, 10, 30 and 60 minutes and mortality was recorded at 24 houses after exposure. Each test was performed in five replicates with simultaneous controls the negative controls were impregnated with ethyl alcohol.

Statistical analysis

The data were pooled and analyzed by standard probit analysis to obtain a KT_{50} and LC_{50}. The knockdown and mortality data were statistically analyzed using one-way ANOVA and the data means were compared by Duncan's multiple range test. Statistical significance was set at $p<0.05$. The levels of susceptibility were categorized according to WHO criteria (WHO, 1998): 98-100% mortality = susceptible, 80-97% mortality = possible resistance, and < 80% mortality = resistance. Where control mortality exceeded 20% the whole test was rejected and repeated. Where control mortality was 5-20%, the results were corrected using Abbott's formula.

RESULTS

The knockdown rates and KT_{50} values

Table 1
List of herbal essential oils tested in this study.

Scientific name	Common name	Family	Perported therapeutic properties
Allium sativum L.	Garlic	Amarylidaceae	Antiseptic, antibacterial, stimulating digestion, reducing high blood pressure, glandular regulator, diuretic and even cancer deterrent.
Cananga odorata (Lamk) Hook f.&Thomson	Ylang-ylang	Annonaceae	Antidepressant, antifungal, antiseptic, antispasmodic, aphrodisiac, calmative, hypotensive, nervine and tonic.
Illicium verum Hook f.	Star anise	Illiciaceae	Anti-spasmodic, antifungal, antibacterial, carminative, stomachic, stimulant, diuretic properties, rheumatism and insecticide.
Ocimum basilicum L.	Sweet basil	Labiatae	Anatiemetic, antiseptic, expectorant, immune support and insecticide.
Lavandula angustifolia Mill	Lavender	Lamiaceae	Analgesic, antidepressant, antifungal, anti-inflammatory, antirheumatic, antiseptic, antispasmodic, calmative, cholagogue, choleretic, cicatrizant, cytophylactic, deodorant, diuretic, emmenagogue, hypotensive, nervine, tonic and vulnerary.
Mentha cordifolia Opiz	Kitchen mint	Lamiaceae	Carminative, mild antiseptic, local anesthetic, diaphoretic and digestant properties.
Mentha piperita L.	Peppermint	Lamiaceae	Analgesic, anesthetic, antiseptic, antigalactagogue, antiphlogistic, antispasmodic, astringent, carminative, cephalic, cholagogue, cordial, decongestant, emmenagogue, expectorant, febrifuge, hepatic, nervine, stimulant, stomachic, sudorific, vasoconstrictor and vermifuge.
Cinnamon verum J. Presl	Cinnamon	Lauraceae	Analgesic, antiseptic, antibiotic, antispasmodic, aphrodisiac, astringent, cardiac, carminative, emmenagogue, insecticide, stimulant, stomachic, tonic and vermifuge.
Litsea petiolata Hook.f.	Tummung	Lauraceae	Protective agents against DNA damage and antimutagenic.
Eucalyptus globulus Labill	Eucalyptus	Myrtaceae	Analgesic, antifungal, antineuralgic, antirheumatic, antiseptic, antispasmodic, decongestant, depurative, expectorant, febrifuge, immune tonic, rubefacient, stimulant, vulnerary and insecticidal.
Syzygium aromaticum (L.) Merrill&Perry	Clove	Myrtaceae	Antiviral, antimicrobial, antifungal, general stimulating, hypertensive aphrodisiac, light stomachic, carminative, anesthetic.
Cymbopogon citratus (DC.) Stapf	Lemongrass	Poaceae	Analgesic, antifungal, anti-inflammatory, antiseptic, antiviral, bactericidal, digestive, febrifuge, tonic and insecticidal.
Cymbopogon nardus (L.) Rendle	Citronella grass	Poaceae	Antiseptic, bactericidal, deodorant, diaphoretic, parasitic, tonic, stimulant, and insecticide.

Table 1 (Continued).

Scientific name	Common name	Family	Perported therapeutic properties
Citrus madurensis Lour	Calamodin	Rutaceae	Antiseptic, antispasmodic, calmative, digestive, diuretic, laxative, sedative, tonic.
Citrus sinensis (L.) Osbeck	Sweet orange	Rutaceae	Antidepressant, antiseptic, antispasmodic, calmative, carminative, cholagogue, choleretic, stomachic and tonic.
Zanthozylum limonella Alston	Makhaen	Rutaceae	Cancer treatment, anti-oxidant, anti-coagulant and anti-bacterial agents.
Alpinia galanga (L.) Wild	Galanga	Zingiberaceae	Carminative, antituberculosis and stimulant properties.
Curcuma amada Roxb	Mango ginger	Zingiberaceae	Antioxidant, antibacterial, antifungal, anti-inflammatory, platelet aggregation inhibitory, cytotoxicity, antiallergic, hypotriglyceridemic, enterokinase inhibitory, CNS depressant and analgesic.
Zingiber cussumunar Roxb	Phlai	Zingiberaceae	Antiseptic, antitoxic and strong anti-inflammatory effect.
Zingiber officinale Roscoe	Ginger	Zingiberaceae	Immuno-modulatory, anti-tumorigenic, anti-inflammatory, anti-apoptotic, anti-hyperglycemic, anti-lipidemic, anti-emetic actions and strong anti-oxidant.

for the 20 essential oils at 1, 5 and 10% concentration against houseflies are shown in Table 2. At a concentration of 1%, 11 essential oils had KT_{50} values of >60 minutes. The essential oil derived from *C. verum* was the most efficient with a KT_{50} value of 61.0 minutes. Ten essential oils gave KT_{50} values from 79.6 to 172.7 minutes. In nine essential oils (*A. sativum*, *C. odorata*, *O. basilicum*, *E. globulus*, *C. madurensis*, *Z. limonella*, *A. galanga*, *C. amada* and *Z. cussumunar*) there was no KT_{50}. At 5% concentration, *C. citratus* and *M. piperita* had a KT_{50}< 10 minutes and 100% knockdown at 30 and 60 minutes. The KT_{50} values for *C. citratus* and *M. piperita* were 6.7 and 6.9 minutes, respectively. The KT_{50} values for *L. angustifolia*, *L. petiolata* and *I. verum*, which were 22.3, 22.8 and 23.9 minutes, respectively. Ten other essential oils gave KT_{50} values between 31.4 to 101.2 minutes. In five essential oils there was no KT_{50}. At 10% concentration, *C. citratus*, *M. piperita* and *L. angustifolia* had 100% knockdown at 30 and 60 minutes. The KT_{50} values for *C. citratus, M. piperita* and *L. angustifolia* were 5.1, 5.4 and 8.2 minutes, respectively. The essential oils with a KT_{50}< 20 minutes were *L. petiolata*, *Z. cussumunar* and *I. verum*, with KT_{50} values of 16.7, 17.4 and 18.7 minutes, respectively. Twelve essential oils had KT_{50} values between 22.3 to 93.1 minutes. There were no KT_{50} values for *C.madurensis* and *C. amada*.

The mortality rates, susceptibilities and LC_{50} values for the 20 essential oils are shown in Table 3. Houseflies were resistant to all 20 essential oils at 1% concentration with mortality rates ranging from 0 to 24%. At 5% concentration *L. angustifolia*

Table 2
KT_{50} values and percent knockdown of houseflies at 1, 5 and 10% concentration of twenty essential oils at 5, 10, 30 and 60 minutes post-exposure.

Herbal essential oils	1% Concentration					5% Concentration					10% Concentration				
	5 min	10 min	30 min	60 min	KT_{50} (min)	5 min	10 min	30 min	60 min	KT_{50} (min)	5 min	10 min	30 min	60 min	KT_{50}(min)
Allium sativum	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	0^{E}	2 ± 4.47^{F}	93.05	0^{C}	0^{G}	0^{D}	2 ± 4.47^{D}	93.05
Cananga odorata	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	16 ± 16.73^{DE}	34 ± 27.02^{D}	68.09	0^{C}	4 ± 5.48^{G}	50 ± 7.07^{C}	70 ± 15.81^{BC}	42.40
Illicium verum	0	0	0^{B}	6 ± 8.94^{B}	79.58	0^{B}	16 ± 8.94^{D}	78 ± 8.37^{B}	98 ± 4.47^{AB}	23.87	0^{C}	32 ± 8.37^{E}	86 ± 11.40^{AB}	100^{A}	18.66
Ocimum basilicum	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	0^{E}	0^{F}	ns	0^{C}	0^{G}	4 ± 8.94^{D}	18 ± 19.24^{D}	84.25
Lavendula angustifolia	0	0	0^{B}	2 ± 4.47^{B}	93.05	0^{B}	52 ± 20.49^{B}	80 ± 14.14^{B}	92 ± 8.37^{AB}	22.26	8 ± 13.04^{C}	78 ± 8.37^{B}	100^{A}	100^{A}	8.23
Mentha cordifolia	0	0	0^{B}	4 ± 5.48^{B}	84.83	0^{B}	4 ± 8.94^{E}	20 ± 33.91^{CD}	30 ± 30.00^{DE}	73.07	0^{C}	24 ± 23.02^{EF}	48 ± 39.62^{C}	52 ± 43.24^{C}	48.87
Mentha piperita	0	0	4 ± 5.48^{B}	6 ± 8.94^{B}	124.50	28 ± 20.49^{A}	86 ± 5.48^{A}	100^{A}	100^{A}	6.89	54 ± 20.74^{A}	94 ± 8.94^{A}	100^{A}	100^{A}	5.36
Cinnamon verum	0	0	24 ± 15.17^{A}	42 ± 21.68^{A}	61.03	0^{B}	4 ± 5.48^{E}	32 ± 21.68^{CD}	58 ± 33.47^{C}	51.04	0^{C}	8 ± 10.95^{G}	38 ± 27.75^{C}	70 ± 25.50^{BC}	44.37
Litsea petiolata	0	0	4 ± 8.94^{B}	8 ± 13.04^{B}	112.05	0^{B}	56 ± 11.40^{B}	82 ± 20.49^{AB}	88 ± 16.43^{AB}	22.83	0^{C}	68 ± 10.95^{BC}	90 ± 14.14^{A}	96 ± 8.94^{A}	16.72
Eucalyptus globulus	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	0^{E}	0^{F}	ns	0^{C}	0^{G}	0^{D}	2 ± 4.47^{D}	93.05
Syzygium aromaticum	0	0	0^{B}	6 ± 8.00^{B}	79.58	2 ± 4.00^{B}	30 ± 26.08^{C}	72 ± 13.27^{B}	78 ± 17.20^{B}	31.40	8 ± 11.66^{C}	52 ± 26.38^{D}	82 ± 19.39^{AB}	88 ± 11.66^{AB}	22.32
Cymbopogon citratus	0	0	2 ± 4.47^{B}	6 ± 8.94^{B}	116.11	30 ± 23.45^{A}	88 ± 10.95^{A}	100^{A}	100^{A}	6.69	56 ± 23.02^{A}	96 ± 5.48^{A}	100^{A}	100^{A}	5.14
Cymbopogon nardus	0	0	2 ± 4.47^{B}	2 ± 4.47^{B}	172.69	0^{B}	2 ± 4.47^{E}	38 ± 13.04^{C}	48 ± 10.95^{CD}	54.60	0^{C}	14 ± 19.49^{FG}	68 ± 16.43^{B}	78 ± 16.43^{AB}	34.68
Citrus madurensis	0	0	0^{B}	0^{b}	ns	0^{B}	0^{E}	0^{E}	0^{F}	ns	0^{C}	0^{G}	0^{D}	0^{D}	ns
Citrus sinensis	0	0	0^{B}	2 ± 4.47^{b}	93.05	0^{B}	0^{E}	0^{E}	4 ± 5.48^{F}	84.83	0^{C}	0^{G}	2 ± 4.47^{D}	16 ± 11.40^{D}	84.31
Zanthozylum limonella	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	0^{E}	0^{F}	ns	0^{C}	0^{G}	0^{D}	4 ± 8.94^{D}	84.83
Alpinia galanga	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	0^{E}	4 ± 5.48^{F}	84.83	0^{C}	0^{G}	2 ± 4.47^{D}	16 ± 20.74^{D}	84.31
Curcuma amada	0	0	0^{B}	0^{B}	ns	0^{B}	0^{E}	0^{E}	0^{F}	ns	0^{C}	0^{G}	0^{D}	0^{D}	ns
Zingiber cussumunar	0	0	0^{B}	0^{B}	ns	0^{B}	2 ± 4.47^{E}	14 ± 31.30^{DE}	14 ± 31.30^{EF}	101.19	24 ± 23.02^{B}	62 ± 27.75^{CD}	86 ± 20.74^{AB}	90 ± 22.36^{AB}	17.37
Zingiber officinale	0	0	0^{B}	2 ± 4.47^{B}	93.05	0^{B}	0^{E}	0^{E}	6 ± 8.94^{F}	79.58	0^{C}	0^{G}	0^{D}	10 ± 10.00^{D}	72.05
Negative control	0	0	0^{B}	0^{B}		0^{B}	0^{E}	0^{E}	0^{F}		0^{C}	0^{G}	0^{D}	0^{D}	
CV%	0	0	248.14	174.30		240.31	56.86	45.62	41.73		130.69	47.72	33.90	31.82	

KT_{50}, 50% knockdown time: ns, not computed by Probit analysis
Mean % knockdown in each column followed by the same letter are not significantly different (one-way ANOVA and Duncan's multiple range test).

Table 3
The mortality rates and LC_{50} values against houseflies among twenty essential oils.

Herbal essential oils	1% Concentration		5% Concentration		10% Concentration		LC_{50} at 24 hrs
	% Mortality	Susceptibility	% Mortality	Susceptibility	% Mortality	Susceptibility	
Allium sativum	0^{B}	R	$14±8.94^{CDEF}$	R	$28±21.68^{EFG}$	R	13.03
Cananga odorata	$2±4.47^{B}$	R	$28±27.75^{BCDE}$	R	$54±28.81^{DE}$	R	9.05
Illicium verum	$12±13.04^{B}$	R	$40±25.50^{BC}$	R	$48±35.64^{DE}$	R	9.48
Ocimum basilicum	$2±4.47^{B}$	R	$2±4.47^{EF}$	R	$6±8.94^{G}$	R	35.44
Lavendula angustifolia	$8±8.37^{B}$	R	$86±5.48^{A}$	RS	100^{A}	S	3.26
Mentha cordifolia	$6±8.94^{B}$	R	$24±32.09^{BCDEF}$	R	$58±35.64^{BCDE}$	R	8.87
Mentha piperita	$8±10.95^{B}$	R	$98±4.47^{A}$	S	100^{A}	S	2.62
Cinnamon verum	$24±25.10^{A}$	R	$48±34.21^{B}$	R	$56±26.08^{CDE}$	R	7.48
Litsea petiolata	$6±8.94^{B}$	R	$80±20.00^{A}$	RS	$86±21.91^{AB}$	RS	4.38
Eucalyptus globulus	0^{B}	R	0^{F}	R	$2±4.47^{G}$	R	15.32
Syzygium aromaticum	$4±4.90^{B}$	R	$42±34.29^{B}$	R	$60±25.30^{BCD}$	R	7.85
Cymbopogon citratus	$4±5.48^{B}$	R	100^{A}	S	100^{A}	S	2.22
Cymbopogon nardus	$2±4.47^{B}$	R	$32±29.50^{BCD}$	R	$42±38.99^{DEF}$	R	10.38
Citrus madurensis	0^{B}	R	0^{F}	R	$2±4.47^{G}$	R	15.31
Citrus sinensis	$8±17.89^{B}$	R	$28±19.24^{BCDE}$	R	$54±20.74^{DE}$	R	9.16
Zanthozylum limonella	0^{B}	R	0^{F}	R	$4±8.94^{G}$	R	13.87
Alpinia galanga	$4±5.48^{B}$	R	$6±5.48^{DEF}$	R	$16±20.74^{FG}$	R	21.41
Curcuma amada	0^{B}	R	$2±4.47^{EF}$	R	$8±8.37^{G}$	R	15.72
Zingiber cussumunar	0^{B}	R	$4±8.94^{EF}$	R	$84±30.50^{AB}$	RS	8.18
Zingiber officinale	$4±5.48^{B}$	R	$6±8.94^{DEF}$	R	$10±7.07^{G}$	R	34.46
Negative control	0^{B}		0^{F}		0^{G}		
CV%	198.02		60.29		48.47		

LC_{50}, 50% lethal concentration.
Mean % mortality in each column followed by the same letter are not significantly different (one-way ANOVA and Duncan's multiple range test).
S, Susceptible is defined as 98-100% mortality; RS, Possible resistance is defined as 80-97% mortality; R, Resistance is defined as <80% mortality.

and *L. petiolata*, gave mortality rates of 86 and 80%, respectively. *C. citratus* and *M. piperita* gave mortality rates of 100% and 98%, respectively. Sixteen essential oils gave mortality rates of 0 to 48%. At 10% concentration the mortality rates and susceptibilities increased. The mortality rates for *Z. cussumunar*, *L. petiolata*, *L. angustifolia* and *M. piperita* were 84, 86, 100 and 100%, respectively. There were significant differences in mean mortality rates using the one-way ANOVA. Fifteen essential oils gave mortality rates of 2 to 60%. The LC_{50} values at 24 hours after exposure for *C. citratus*, *M. piperita* and *L. angustifolia* were 2.2, 2.6 and 3.3 minutes, respectively.

DISCUSSION

At 10% concentration the essential oils from *C. citratus*, *M. piperita* and *L. angustifolia* had high knockdown rates and the houseflies were susceptible. Samarasekera *et al* (2006) also found *C. citratus* oil gave good knockdown rates and mortality at a KD_{50} of 0.69 g/insect and an LD_{50} of 1.71 g/insect against adult *M. domestica* in Sri Lanka. Phasomkusolsil and Soonwera (2011) found *C. citratus* oil gave high knockdown rates and insecticidal activity against three adult mosquitoes species *Aedes aegypti*, *Culex quinquefasciatus* and *Anopheles dirus*, with LC_{50} values of < 0.1, 2.2 and < 0.1%, respectively. A 10% concentration of *C. citratus* resulted in 100% mortality 24 hours after exposure.

M. piperita essential oil had the highest housefly larvicidal properties with a LC_{50} value of 104 ppm and exhibited 96.8% repellency and 98.1% oviposition deterrence at a 1% concentration (Morey and Khandagle, 2012). Kumar *et al* (2012a) found *M. piperita* oil achieved housefly larval LC_{50} of 0.54 l/cm^2 by contact and an LC_{50} of 48.4 l/l by fumigation; it also caused 100% suppression on contact and with fumigation. Kumar *et al* (2011) found *M. piperita* gave LC_{50} and LC_{90} larvicidal values against *Aedes aegypti* of 111.9 and 295.18 ppm, respectively, at 24 hours after exposure, and 100% repellency for up to 150 minutes. Purwal *et al* (2010) found a combination of *C. citratus* and *M. piperita* oils caused a mean time to death among *Pediculus humanus* of 60 minutes. Talbert and Wall (2012) found *M. piperita* and *L. angustifolia* caused 100% mortality among the chewing louse, *Bovicola* (*Werneckiella*) *ocellatus* at concentrations of 5-10% (v/v). Pavela (2005) found *L. angustifolia* was highly toxic against the larvae *Spodoptera littoralis,* with an $LD_{50} \leq 0.05$ l/larva.

Our findings show *C. citratus*, *M. piperita* and *L. angustifolia* had insecticidal properties against *Musca domestica* L. Some of the chemical compoments of these oils may interfere with the nervous systems in insects. The main components of *C. citratus* oil are citral and terpenes, *M. piperita* contains menthol, carvone and limonene, and *L. angustifolia* oil has linalool, linalyl acetate and b-Caryophyllene (Negrelle and Gomes, 2007; Djiani and Dicko, 2012). Many essential oils are relatively non-toxic to mammals and fish in toxicological tests, and meet the criteria for reduced risk pesticides (Koul *et al*, 2008). *C. citratus*, *M. piperita* and *L. angustifolia* essential oils have the potential to be an effective method to control houseflies. However, laboratory results may differ from field results. Therefore, lemongrass, peppermint and lavender oils should be further studied for housefly control.

ACKNOWLEDGEMENTS

This research was supported by the Entomology and Environment Program, Faculty of Agricultural Technology, King

Mongkut Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand.

REFERENCES

Banjo AD, Lawal OA, Adeduji OO. Bacteria and fungi isolated from housefly (*Musca domestica* L.) larvae. *Afr J Biotechnol* 2005; 4: 780-4.

Batish RB, Harminder PS, Ravinder KK, Shalinder K. Eucalyptus essential oil as a natural pesticide. *Forest Ecol Manage* 2008; 256: 2166-74.

Djiani A, Dicko A. The therapeutic benefits of essential oils. New York: Intechweb, n.d. [Cited 2012 Aug 3]. Available from: URL: http://cdn.intechweb.org/pdfs/29979.pdf

Dogra SS, Mahajan VK. Oral myiasis caused by *Musca domestica* larvae in child. *Int J Pediatr Otorhinolaryngol Extra* 2010; 5: 105-7.

Edris AE. Pharmaceutical and therapeutic potentials of essential oils and their individual volatile constituents: a review. *Phytother Res* 2007; 21: 308-23.

Fasanella A, Scasciamacchia S, Garofolo G, Giangaspero A, Tarsitano E, Adone R. Evaluation of the house fly *Musca domestica* as a mechanical vector for an antrax. *Plos one* 2005; 5: 1-5.

Harwood RF, James MT. Entomology in human and animal health. 7th ed. New York: Macmillan Publishing, 1979.

Koul O, Walia S, Dhaliwal GS. Essential oils as green pesticides: potential and constraints. *Biopestic Int* 2008; 4: 63-84.

Kumar P, Mishra S, Malik A, Satya S. Efficacy of *Mentha* x *piperita* and *Mentha citrata* essential oils against housefly, *Musca domestica* L. *Industr Crops Products* 2012a; 39:106-12.

Kumar P, Mishra S, Malik A, Satya S. Insecticidal evaluation of essential oils of *Citrus sinensis* L. (Myrtales: Myrtaceae) against housefly, *Musca domestica* L. (Diptera: Muscidae). *Parasitol Res* 2012b; 110: 1929-36.

Kumar S, Wahab N, Warikoo R. Bioefficacy of *Mentha piperita* essential oil against dengue fever mosquito *Aedes aegypti* L. *Asian Pac J Trop Biomed* 2011; 85-8.

Morey RA, Khandagle AJ. Bioefficacy of essential oils of medicinal plants against housefly, *Musca domestica* L. *Parasitol Res* 2012; 111: 1799-805.

Negrelle RRB, Gomes EC. *Cymbopogon citratus* (DC.) Stapf: chemical composition and biological activities. *Rev Bras Pl Med Botucatu* 2007; 9: 80-92.

Olsen AR, Gecan JS, Ziobro GC, Bryce JR. Regulatory action criteria for filth and other extraneous materials. V. Strategy for evaluating hazardous and nonhazardous filth. *Regulat Toxicol Pharmacol* 2001; 33: 363-92.

Palacios SM, Bertoni A, Rossi Y, Santander R, Urzua A. Efficacy of essential oils from edible plants as insecticides against the house fly, *Musca domestica* L. *Molecules* 2009a; 14: 1938-47.

Palacios SM, Bertoni A, Rossi Y, Santander R, Urzua A. Insecticidal activity of essential oils from native medicinal plants of central Argentina against the house fly, *Musca domestica* (L.). *Parasitol Res* 2009b; 106: 207-12.

Pavela R. Insecticidal activity of some essential oils against larvae of *Spodoptera littoralis. Fitoterapia* 2005; 76: 691-6.

Pavela R. Insecticidal properties of several essential oils on the house fly (*Musca domestica* L.). *Phytothe Res* 2008; 22: 274-8.

Phasomkusolsil S, Soonwera M. Efficacy of herbal essential oils as insecticide against *Aedes aegypti* (Linn.), *Culex quinquefasciatus* (Say) and *Anopheles dirus* (Peyton and Harrison). *Southeast Asian J Trop Med Public Health* 2011; 42: 1083-92.

Purwal L, Shrivastava V, Jain U. Assessment of pediculicidal potential of formulation containing essential oils of *Mentha piperita* and *Cymbopogon citratus*. *Res J Pharmaceut Biol Sci* 2010; 1: 366-72.

Samarasekera R, Kalhari KS, Weerasinghe IS. Insecticidal activity of essential oils of *Ceylon cinnamomum* and *Cymbopogon* species against *Musca domestica*. *J Essent Oil*

Res 2006; 18: 352-4.

Sangmaneedet S, Kanistanon K, Papirom P, Tesiri T. Uses of Thai medicinal herb (*Derris elliptica* (Roxb.) Benth) in control of fly larvae population and its application in the treatment of cutaneous myiasis in animals. *Khon Kaen Univ Res J* 2005; 10: 22-30.

Scott JG, Alefantis TG, Kaufman PE, Rutz DA. Insecticide resistance in houseflies from caged-layer poultry facilities. *Pest Manage Sci* 2000; 56: 147-53.

Shono T, Scott JG. Spinosad resistance in the housefly, *Musca domestica*, is due to a recessive factor on autosome. 1. *Pestic Biochem Physiol* 2003; 75: 1-7.

Srinivasan R, Jambulingam P, Gunasekaran K, Boonpathidoss PS. Tolerance of housefly, *Musca domestica* L. (Diptera: Muscidae) to dichlorvos (76% EC) an insecticide used for fly control in the tsunami-hit coastal villages of southern India. *Acta Trop* 2008; 105: 187-90.

Stroh J, Wan MT, Isman MB, Moul DJ. Evaluation of the acute toxicity to juvenile Pacific coho salmon and rainbow trout of some plant essential oils, a formulated product, and the carrier. *Bull Environ Contam Toxicol* 1998; 60: 923-30.

Talbert R, Wall R. Toxicity of essential and non-essential oils against the chewing louse, *Bovicola* (*Werneckiella*) *ocellatus*. *Res Vet Sci* 2012; 93: 831-5.

Ugbogu OC, Nwachukwu NC, Ogbuagu UN. Isolation of *Salmonella* and *Shigella* species from houseflies (*Musca domestica* l.) in Utaru, Nigeria. *Afr J Biotechnol* 2006; 5: 1090-1.

Wattanachai P, Sooppapathom K, Tintanon B, Phun-urai P. Susceptibility of house fly (*Musca domestica*) to different compound in Thailand, 1993-1995. *J Health Sci* 1996; 5: 572-5.

World Health Organization (WHO). Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces. *WHO/CDS/CPC/MAL/98.12*.1998.

World Health Organization (WHO). Guidelines for testing mosquito adulticides for indoor residual spraying and treatment of mosquito nets. *WHO/CDS/NTD/WHOPES/GCDPP/2006.3*. 2006.

Yap KL, Kalpana M, Lee ILL. Wings of the commom house fly (*Musca domestica* L.): importance in mechanical transmission of *Vibrio cholerae*. *Trop Biomed* 2008; 25: 1-8.