

## **Bioactivity of Argentinean Essential Oils Against Permethrin-Resistant Head Lice, *Pediculus humanus capitis***

Authors: Toloza, Ariel C, Zygadlo, Julio, Biurrun, Fernando, Rotman, Alicia, and Picollo, María I

Source: Journal of Insect Science, 10(185) : 1-8

Published By: Entomological Society of America

URL: <https://doi.org/10.1673/031.010.14145>

---

BioOne Complete ([complete.BioOne.org](https://complete.BioOne.org)) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at [www.bioone.org/terms-of-use](https://www.bioone.org/terms-of-use).

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

---

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.



## Bioactivity of Argentinean essential oils against permethrin-resistant head lice, *Pediculus humanus capitis*

Ariel C Toloza<sup>1\*</sup>, Julio Zygodlo<sup>2</sup>, Fernando Biurrun<sup>3</sup>, Alicia Rotman<sup>4</sup>, and María I Picollo<sup>1</sup>

<sup>1</sup> Centro de Investigaciones de Plagas e Insecticidas (CITEFA-CONICET), Juan Bautista de La Salle 4397, B1603ALO, Villa Martelli, Buenos Aires, Argentina

<sup>2</sup> Cátedra de Química Orgánica, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, IMBIV-CONICET, Córdoba, Argentina

<sup>3</sup> Laboratorio de diversidad vegetal y fitosociología, INTA EEA La Rioja, Argentina

<sup>4</sup> Cátedra de Botánica General, Universidad Nacional de Jujuy, Argentina

### Abstract

Infestation with the head louse, *Pediculus humanus capitis* De Geer (Phthiraptera: Pediculidae), is one of the most common parasitic infestation of humans worldwide. Traditionally, the main treatment for control of head lice is chemical control that is based in a wide variety of neurotoxic synthetic insecticides. The repeated overuse of these products has resulted in the selection of resistant populations of head lice. Thus, plant-derived insecticides, such as the essential oils seem to be good viable alternatives as some have low toxicity to mammals and are biodegradable. We determined the insecticidal activity of 25 essential oils belonging to several botanical families present in Argentina against permethrin-resistant head lice. Significant differences in fumigant activity against head lice were found among the essential oils from the native and exotic plant species. The most effective essential oils were *Cinnamomum porphyrium*, followed by *Aloysia citriodora* (chemotype 2) and *Myrcianthes pseudomato*, with  $KT_{50}$  values of 1.12, 3.02 and 4.09; respectively. The results indicate that these essential oils are effective and could be incorporated into pediculicide formulations to control head lice infestations once proper formulation and toxicological tests are performed.

**Keywords:** human head louse, Argentinean plants, biopesticides, fumigant activity

**Correspondence:** \* [atoloza@citefa.gov.ar](mailto:atoloza@citefa.gov.ar)

**Received:** 2 February 2010, **Accepted:** 9 March 2010

**Copyright :** This is an open access paper. We use the Creative Commons Attribution 3.0 license that permits unrestricted use, provided that the paper is properly attributed.

**ISSN:** 1536-2442 | Vol. 10, Number 185

#### Cite this paper as:

Toloza AC, Zygodlo J, Biurrun F, Rotman A, Picollo M. 2010. Bioactivity of Argentinean essential oils against permethrin-resistant head lice, *Pediculus humanus capitis*. *Journal of Insect Science* 10:185 available online: [insectscience.org/10.185](http://insectscience.org/10.185)

## Introduction

Infestation with the louse, *Pediculus humanus capitis* De Geer (Phthiraptera: Pediculidae) is one of the most common parasitic infestation of humans worldwide (Burgess 2004). Children 3-12 years of age are the most affected group in both developed and developing countries. The main symptoms associated with infestation are constant itching, scalp irritation and social sanctioning. In rare cases, the itch-scratch cycle can lead to secondary infection with impetigo and pyoderma (Mumcuoglu et al. 2009). Transmission of head louse occurs mainly by direct host-to-host contact (Takano-Lee et al. 2005). Moreover, Falagas et al. (2008) reported that head louse infestation has been increasing worldwide due to the lack of effectiveness of pediculicides.

Traditionally, the main treatment to control head lice is chemicals including a wide variety of neurotoxic synthetic insecticides such as DDT, lindane, malathion, carbaryl, permethrin and  $\delta$ -phenothrin (Burgess 2004). The repeated overuse of these products has resulted in the selection of resistant populations of head lice in several countries, including Argentina (Mumcuoglu et al. 1995; Picollo et al. 1998; 2000; Kasai et al. 2009). There is a strong consumer pressure against insecticide use that impacts health, the food supply, water and the environment (Isman 2008). Thus, there is an urgent need to find and develop new pediculicide substances. Plant essential oils and their constituent compounds such as the monoterpenoids seem to be good candidates because many are easily extractable, are biodegradable, and are very effective against a wide spectrum of insect pests (Isman 2000; Rahman and Talukder 2006), including head lice (Priestley et al.

2006; Rossini et al. 2008). In a previous study, we reported the fumigant and repellent activity of many native aromatic plants belonging to six botanical families against head lice (Toloza et al. 2006). In order to continue this work, the purpose of the current study was to assess the insecticidal activity of essential oils from native and cultivated aromatic plants from Argentina for their activity against permethrin-resistant head lice.

## Methods and Materials

### Insects

Head lice were collected from heads of 2,120 infested children 6-13 years old, using a fine toothed antilouse metallic comb. Lice were obtained from three elementary schools (HB, PR and E14) located in Buenos Aires, where a topical method indicated high resistance levels to permethrin (71.42, 35.37 and 33.33; respectively) (Toloza AC, unpublished). Briefly, this method consisted of the topical application of serial dilutions of permethrin in acetone. They were applied to individual lice with a 5- $\mu$ l syringe, and each louse was treated with 0.1  $\mu$ l of the solution on the dorsal abdomen. Each concentration was replicated at least three times using 10 adults per replicate. Once collected, head lice were transported to our laboratory according to Picollo et al. (1998, 2000). The protocol for lice collection was approved by the ad hoc committee of the Centro de Investigaciones de Plagas e Insecticidas (CIPEIN, Buenos Aires, Argentina), and archived in our laboratory. After collection, head lice were maintained without feeding in an environmental chamber (Lab-line Instruments, www.lab-line.com) at  $18 \pm 0.5^\circ\text{C}$  and 70-80% RH in darkness.

### Essential oils

Twenty five species of native and exotic plants in thirteen different families were collected in the spring of 2006 and 2007 from different regions of Argentina. Four of these plants, *Aloysia citriodora*, *Satureja parvifolia*, *Baccharis salicifolia* and *Chenopodium ambrosioides*, were the most effective. They were obtained from different environmental areas that allowed separating them into different chemotypes.

Voucher specimens were deposited at Jujuy Herbarium (Index herbarium code JUA) and INTA EEA La Rioja Herbarium (CHAM). The species are listed in Table 1 and the Appendix ([View appendix](#)).

Dried leaves of each individual species were hydrodistilled in a Clevenger-like apparatus for 1 h. The oils obtained were dried over anhydrous sodium sulphate (Merck, [www.syngentacropprotection.com](http://www.syngentacropprotection.com)) and stored in a refrigerator until analysis.

### Gas chromatography (GC)

Analyses of essential oils were performed in a Shimadzu GC-R1A (FID) gas-chromatograph ([www.shimadzu.com](http://www.shimadzu.com)), fitted with a 30 m x 0.25 mm (0.25 µm film thickness) fused silica capillary column coated with a phase 5% phenyl 95% dimethylpolysiloxane, non polar DB-5 column. The GC operating conditions were as follows: oven temperature programmed from 40 -230° C at 2° C/min, injector and detector temperatures 240° C. The carrier gas was nitrogen at a constant flow of 0.9 ml/min, and 0.3 µl of each material was injected into the chromatograph. The constituents of the essential oils were identified on the basis of: (1) their GC retention index with reference to an homologous series of n-alkanes (C12 - C25); (2) by comparison of their retention times

with those of pure authentic samples from Sigma and Fluka Companies; (3) peak enrichment on co-injection with authentic standards wherever possible; (4) by GC-MS library search (Adams and Nist); and (5) using visual inspection of the mass spectra from literature, for confirmation. Analyses were performed with a Perkin Elmer Q-700 ([www.perkinelmer.com](http://www.perkinelmer.com)) equipped with a SE-30 capillary column (30 m x 0.25 mm; coating thickness 0.25 µm film). The analytical conditions were: oven temperature from 40° C to 230° C at 2° C/min, the carrier gas was helium at a constant flow of 0.9 ml/min, the source was at 70 eV.

### Bioassay

The method of Toloza et al. (2006) was employed to evaluate the fumigant activity of the essential oils. Briefly, it consisted of an enclosed chamber (9 cm diameter Petri dish) that allowed creating a saturated microatmosphere as a result of the evaporation of the essential oil, thus exerting inactivation on lice. A drop of 60 µl of pure essential oil was deposited on a micro coverglass within the chamber. Control consisted of the same experimental unit without the addition of any substance. In each chamber 15 adult insects (males and females) were placed and exposed to the vapors of the essential oils. Lice were observed for evidence of knockdown every 5 min. for 60 min. The criterion for knockdown was when an insect remain on its back with no leg movements. Once used in a given assay, the insects were discarded. Three replicates were made for each tested essential oil. During each study, the assembled units were kept at  $28 \pm 1^\circ \text{C}$  and  $60 \pm 5\% \text{RH}$ .

### Statistical analysis

Probit analysis (Litchfield and Wilcoxon 1949) was used to estimate time in minutes to

knockdown of 50% of exposed insects of each experimental unit ( $KT_{50}$ ), by using POLO Plus v2.0 (LeOra Software 2002). Insects exposed to test essential oils that did not show evidence of efficacy in 60 min, were considered to possess a  $KT_{50} > 60$  min and were not included in further statistical analysis. Samples for which the 95% fiducial limits did not overlap were considered to be significantly different.

## Results

Significant differences in fumigant activity against head lice were found among the essential oils from the native and exotic plant species (Table 1). Eighteen of the twenty five studied essential oils were native from Argentina (72.0%). It is important to note that

75% of the effective essential oils ( $KT_{50} < 60$ ) were from plants native to Argentina. On the basis of effectiveness, the essential oil from the native *Cinnamomum porphyrium* was the most effective ( $KT_{50} = 1.12$  min), followed by *A. citriodora* (chemotype 2) and *Myrcianthes pseudomato*, with  $KT_{50}$  values of 3.02 and 4.09; respectively. There were significant differences among all the studied chemotypes (Table 1). For example, *A. citriodora* (chemotype 2), *S. parvifolia* (chemotype 2) and *C. ambrosioides* (chemotype 1) showed pediculicidal action, with  $KT_{50}$  values of 3.02, 32.06 and 42.03 min; respectively. This is in contrast to the chemotypes of *A. citriodora* (chemotype 1), *S. parvifolia* (chemotype 1) and *C. ambrosioides* (chemotype 2) that possessed  $KT_{50} > 60$  min. Both chemotypes 1 and 2 of the essential oil *B. salicifolia*

**Table 1.** Fumigant activity of essential oils from aromatic plants.

Botanical family	Essential oil <sup>a</sup>	Fumigant activity <sup>b</sup>			
		Slope $\pm$ SE	$KT_{50}$ , min (CL) <sup>c</sup>	$\chi^2$	df <sup>d</sup>
Apiaceae	<i>Azorella</i> sp. <sup>e</sup>	-	>60 <sup>f</sup>	-	-
	<i>Pimpinella anisum</i> <sup>f</sup>	-	>60 <sup>f</sup>	-	-
Asteraceae	<i>Artemisia annua</i> <sup>e</sup>	6.30 $\pm$ 1.11	41.39 (35.59- 49.36) <sup>de</sup>	14.03	10
	<i>Tagetes filifolia</i> <sup>e</sup>	-	> 60 <sup>f</sup>	-	-
	<i>Tagetes mendocina</i> <sup>e</sup>	-	> 60 <sup>f</sup>	-	-
	<i>Baccharis salicifolia</i> (1) <sup>e</sup>	-	>60 <sup>f</sup>	-	-
	<i>Baccharis salicifolia</i> (2) <sup>e</sup>	-	>60 <sup>f</sup>	-	-
Chenopodiaceae	<i>Baccharis vernicosa</i> <sup>e</sup>	-	>60 <sup>f</sup>	-	-
	<i>Chenopodium ambrosioides</i> (1) <sup>f</sup>	2.22 $\pm$ 0.44	42.03 (33.01- 57.37) <sup>de</sup>	7.50	11
	<i>Chenopodium ambrosioides</i> (2) <sup>f</sup>	-	>60 <sup>f</sup>	-	-
Cupressaceae	<i>Juniperus scopularum</i> <sup>f</sup>	-	>60 <sup>f</sup>	-	-
Euphorbiaceae	<i>Croton piluliferum</i> <sup>e</sup>	-	>60 <sup>f</sup>	-	-
Fabaceae	<i>Adesmia boronioides</i> <sup>e</sup>	-	>60 <sup>f</sup>	-	-
Lamiaceae	<i>Satureja parvifolia</i> (2) <sup>e</sup>	6.75 $\pm$ 1.04	32.06 (28.72- 35.37) <sup>d</sup>	3.74	12
	<i>Satureja parvifolia</i> (1) <sup>e</sup>	-	> 60 <sup>f</sup>	-	-
	<i>Thymus vulgaris</i> <sup>f</sup>	-	>60 <sup>f</sup>	-	-
Lauraceae	<i>Cinnamomum porphyrium</i> <sup>e</sup>	4.94 $\pm$ 0.89	1.12 (0.92- 1.31) <sup>a</sup>	2.38	6
Loganiaceae	<i>Buddleja mendozensis</i> <sup>e</sup>	2.25 $\pm$ 0.43	28.81 (18.97- 45.05) <sup>d</sup>	16.34	10
Monimiaceae	<i>Peumus boldus</i> <sup>f</sup>	5.90 $\pm$ 1.23	52.67 (46.72-61.75) <sup>ef</sup>	1.78	11
Myrtaceae	<i>Myrcianthes pseudomato</i> <sup>e</sup>	4.83 $\pm$ 0.72	4.09 (3.46- 4.65) <sup>c</sup>	2.32	12
	<i>Syzygium aromaticum</i> <sup>e</sup>	-	> 60 <sup>f</sup>	-	-
Schizaeaceae	<i>Anemia tomentosa</i> <sup>e</sup>	-	>60 <sup>f</sup>	-	-
Verbenaceae	<i>Aloysia citriodora</i> (2) <sup>e</sup>	7.05 $\pm$ 1.37	3.02 (2.58- 3.41) <sup>b</sup>	4.01	6
	<i>Aloysia citriodora</i> (1) <sup>e</sup>	-	>60 <sup>f</sup>	-	-
	<i>Aloysia catamarcensis</i> <sup>e</sup>	-	>60 <sup>f</sup>	-	-

<sup>a</sup> Plant species. Three replicates of 15 head lice each (total 45) for each essential oil, observed at 5-min intervals for 1h.

<sup>b</sup> Statistics from probit analysis of knockdown times.

<sup>c</sup> Time to 50% knockdown; CL= 95% confidence limit; values in same column followed by different letters are significantly different at  $p < 0.05$ .

<sup>d</sup> Degrees of freedom

<sup>e</sup> Native of Argentina

<sup>f</sup> Exotic of Argentina

showed no action against head lice.

## Discussion

The present study shows that essential oils from some Argentinean aromatic plants have fumigant activity against head lice. In comparison with our previous work (Toloza et al. 2006), new botanical families have been examined including Loganiaceae, Asteraceae, Monimiaceae, Apiaceae, Cupressaceae, Euphorbiaceae, Fabaceae and Schizaeaceae. This is the first study related to the pediculicidal efficacy of these botanical families. An interesting result was the fumigant activity of the three most effective essential oils from *C. porphyrium*, *A. citriodora* (chemotype 2) and *M. pseudomato*, which were 25.7-, 9.5-, and 7-fold more toxic than the oil of *Buddleja mendozensis*. Yang et al. (2005) studied the fumigant activity of an essential oil from another plant of the same genera, *Cinnamomum zeylanicum*, which was also shown to be effective against head lice. However, a comparison with our results was not possible due to differences in the methodology.

Concerning the variation in chemical composition of the essential oils, it is important to note that the differences found in the fumigant efficacy of the oils *A. citriodora*, *S. parvifolia*, *C. ambrosioides*, are related to their chemical composition. For example, both chemotypes of *C. ambrosioides* had a very different chemical composition. Chemotype 1 possess as their main compounds *trans*-carveol (42.4%), *trans*-pinocarvyl acetate (22.4%) and *cis*-carveol (10.6%), while chemotype 2 has ascaridol as its main compound (99.4%). However, other factors such as the interactions among the constituents could also affect the biological activity of the whole oil (Burgess 2004). Both

chemotypes of *S. parvifolia* had similar chemical composition whose main compounds were piperitone and piperitenone oxide. However, chemotype 2 had a higher proportion of piperitone than chemotype 1 (46.0 and 41.9%; respectively) and a lower proportion of hydrocarbons and oxygen-containing sesquiterpenes (Dambolena et al. 2009). These differences were likely responsible for effectiveness of chemotype 2 against head lice.

There are several well documented studies showing that plant extracts could be used as medicinal products against a broad spectrum of ectoparasites of humans and house animals (Semmler et al. 2009; Burgess 2009). However, most of the mentioned products are derived from fixed oils rather than essential oils. For example, a product containing a neem seed extract was highly effective in *in-vivo* and *in-vitro* tests against head lice (Heukelbach et al. 2006; Abdel-Ghaffar and Semmler 2007). Recently, Burgess et al. (2010) showed in a clinical trial the superiority of a spray containing coconut, ylang ylang and anise oils over a permethrin lotion against head lice.

Our study indicates that certain essential oils from local plants of Argentina were highly effective in the vapor phase against head lice. However, *in vitro* efficacy tests of botanical extracts are only the first step of research and much work is needed before they could be used in a commercial product. The incorporation of excipients (alcohols, etc.) that increase the stability of essential oils is of a great concern since essential oils are highly volatile, and the effectiveness of the product could decay in hours if the formulation is incorrect. For instance, active ingredients that were effective *in vitro* could show low or no activity against lice when incorporated into a

liquid formulation because certain adjuvants or excipients could affect the insecticidal activity once they are incorporated into a formulation. Once the vehicle base and the excipients are selected, a battery of tests for acute and chronic toxicity (e.g., burning sensation, skin irritation, etc) is needed. A final step should consider the *in vivo* efficacy of the product (i.e. in clinical trials).

The present work showed that basic research on essential oils toxicity against head lice should be considered only if the steps mentioned above are completed.

### Acknowledgements

We thank the authorities of the elementary schools where head lice were collected. This investigation received financial support from Agencia Nacional de Promoción Científica y Tecnológica (Argentina), Laboratorio Elea (Buenos Aires), and CONICET (Argentina). We thank two anonymous referees for their helpful comments.

### References

Abdel-Ghaffar F, Semmler M. 2007. Efficacy of neem seed extract shampoo on head lice of naturally infected humans in Egypt. *Parasitology Research* 100: 329-332.

Burgess IF. 2004. Human lice and their control. *Annual Review of Entomology* 49: 457-481.

Burgess IF. 2009. Current treatments for pediculosis capitis. *Current Opinion and Infectious Diseases* 22: 131-136.

Burgess I, Brunton E, Burgess N. 2010. Clinical trial showing superiority of a coconut and anise spray over permethrin 0.43% lotion

for head louse infestation, ISRCTN96469780. *European Journal of Pediatrics* 169: 55-62.

Dambolena J, Zunino M, Rotman A, Ahumada O, Lucini O, Biurrun F, Zygadlo J. 2009. Essential oils of plants used in home medicine in North of Argentina. *Journal of Essential Oil Research* 21: 405-409.

Falagas M, Matthaïou D, Rafailidis P, Panos G, Pappas G. 2008. Worldwide prevalence of head lice. *Emergency Infectious Diseases* 14: 1493-1494.

Gillij Y, Gleiser R, Zygadlo J. 2008. Mosquito repellent activity of essential oils of aromatic plants growing in Argentina. *Bioresource Technology* 99: 2507-2515.

González S, Bandoni A, van Baren C, Lira P, Cerda-García-Rojas C, Joseph-Nathan P. 2004. The essential oil of the aerial parts of *Adesmia boronioides* Hook. f. *Journal of Essential Oil Research* 16: 513-516.

Heukelbach J, Oliveira F, Speare R. 2006. A new shampoo based on neem (*Azadirachta indica*) is highly effective against head lice in vitro. *Parasitology Research* 99: 353-356.

Isman M. 2000. Plant essential oils for pest and disease management. *Crop protection* 19: 603-608.

Isman M. 2008. Perspective botanical insecticides: for richer, for poorer. *Pest Management Science* 64: 8-11.

Kasai S, Ishii N, Natsuaki M, Fukutomi H, Komagata O, Kobayashi M, Tomita T. 2009. Prevalence of *kdr*-like mutations associated with pyrethroid resistance in human head louse populations in Japan. *Journal of Medical Entomology* 46: 77-82.

Lahlou M, Berrada R, Agoumi A, Hmamouchi M. 2000. The potential effectiveness of essential oils in the control of human head lice in morocco. *International Journal of Aromatherapy* 10: 108-123.

Lima B, Agüero M, Zygadlo J, Tapia A, Solis C, Rojas de Arias A, Yaluff G, Zacchino S, Feresin G, Schmeda-Hirschmann G. 2009. Antimicrobial activity of extracts, essential oil and metabolites obtained from *Tagetes mendocina*. *Journal of the Chilean Chemical Society* 54: 68-72.

Litchfield J, Wilcoxon F. 1949. A simplified method of evaluating dose-effect experiments. *Journal of Pharmacology and Experimental Therapeutics* 96: 99-103.

Mougabure Cueto G, Zerba E, Picollo MI. 2008. Evidence of pyrethroid resistance in eggs of *Pediculus humanus capitis* (Phthiraptera: Pediculidae) from Argentina. *Journal of Medical Entomology* 45: 693-697.

Mumcuoglu K, Hemingway J, Miller J, Ioffe-Uspensky I, Klaus S, Ben-Ishai F, Galun R. 1995. Permethrin resistance in the head louse *Pediculus capitis* from Israel. *Medical and Veterinary Entomology* 9: 427-432.

Mumcuoglu K, Gilead L, Ingber A. 2009. New insights in pediculosis and scabies. *Expert Review of Dermatology* 4: 285-302.

Picollo MI, Vassena C, Casadio A, Massimo J, Zerba EN. 1998. Laboratory studies of susceptibility and resistance to insecticides in *Pediculus capitis* (Anoplura: Pediculidae). *Journal of Medical Entomology* 35: 814-817.

Picollo MI, Vassena C, Mougabure Cueto G, Vernetti M, Zerba EN. 2000. Resistance to insecticides and effect of synergists on permethrin toxicity in *Pediculus capitis*

(Anoplura: Pediculidae) from Buenos Aires. *Journal of Medical Entomology* 37: 721-725.

Priestley CM, Burgess I, Williamson EM. 2006. Lethality of essential oil constituents towards the human louse, *Pediculus humanus*, and its eggs. *Fitoterapia* 77: 303-306.

Rahman A, Talukder FA. 2006. Bioefficacy of some plant derivatives that protect grain against the pulse beetle, *Callosobruchus maculatus*. *Journal of Insect Science* 6:03, available online: [www.insectscience.org/6.03](http://www.insectscience.org/6.03).

Rossini C, Castillo L, González A. 2008. Plant extracts and their components as potential control agents against human head lice. *Phytochemistry Reviews* 7: 51-63.

Semmler M, Abdel-Ghaffar F, Al-Rasheid K, Mehlhorn H. 2009. Nature helps: from research to products against blood-sucking arthropods. *Parasitology Research* 105: 1483-1487.

StatSoft. Inc. 2004. STATISTICA (data analysis software system), version 7. [www.statsoft.com](http://www.statsoft.com).

Takano-Lee M, Edman J, Mullens B, Clark JM. 2005. Transmission potential of the human head louse, *Pediculus capitis* (Anoplura: Pediculidae). *International Journal of Dermatology* 44: 811-816.

Toloza AC, Zygadlo J, Mougabure Cueto G, Biurrún F, Zerba E, Picollo MI. 2006. Fumigant and repellent properties of essential oils and component compounds against permethrin-resistant *Pediculus humanus capitis* (Anoplura: Pediculidae) from Argentina. *Journal of Medical Entomology* 43: 889-895.

Vassena C, Mougabure Cueto G, González Audino P, Alzogaray R, Zerba E, Picollo MI. 2003. Prevalence and levels of permethrin resistance in *Pediculus humanus capitis* De Geer (Anoplura: Pediculidae) from Buenos Aires, Argentina. *Journal of Medical Entomology* 40: 447-450.

Yang Y, Lee H, Lee S, Clark JM, Ahn Y. 2005. Ovicidal and adulticidal activities of *Cinnamomum zeylanicum* bark essential oil compounds and related compounds against *Pediculus humanus capitis* (Anoplura: Pediculidae). *International Journal of Parasitology* 35: 1595-1600.