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Development of herbal mosquito coil formulations using mosquito repellent plant materials

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With the increasing cases of mosquito-borne diseases such as dengue, malaria, yellow fever, Japanese encephalitis, and chikungunya, it has been a global concern to control the transmission of these diseases by controlling the mosquito population and protecting from mosquito bites using repellent products. Currently, more studies are being focused on developing safe, efficient, and eco-friendly herbal mosquito repellents by combining herbal plant materials due to the health and environmental concerns of overuse of chemical repellents for a long period. Since the studies on the mosquito repellent activity of plants seem to be quite low, through this study, the collaborating mosquito repellent activity of several selected plants is explored and assessed. The objectives of this study are to develop herbal mosquito coil formulations using mosquito repellent plant materials and to evaluate the bio-efficacy of developed coil formulations using preliminary laboratory studies and field studies. In this study, *Piper betel* (Betel) leaves, *Azadirachta indica* (Neem) leaves, *Ocimum tenuiflorum* (*Maduruthala*) leaves, *Cinnamomum zeylanicum* (Cinnamon) leaf oil, and *Cymbopogon nardus* (Citronella) oil were assessed for their potential mosquito repellent activity. This study was approved by the Ethics Review Committee, University of Kelaniya, Sri Lanka, and ethical clearance was obtained before commencing the study. All of the bio-efficacy tests were conducted according to the World Health Organization (WHO) regulations and guidelines for efficacy testing of household insecticide products. In field studies, a total of 12 developed coil formulations were tested in six different locations using adult human volunteers against a free-flying mosquito population, and efficacy was assessed in terms of biting inhibition. Preliminary laboratory studies were conducted in a glass chamber (20 cm x 20 cm x 20 cm in size) using sucrose-fed female *Aedes aegypti* mosquitoes (2-7 days old) with three replicates for each coil formulation. The number of knocked-down mosquitoes was counted at regular intervals for 60 minutes, and knock-down time (KDT_{50} & KDT_{90}) and mortality of the mosquitoes were recorded after post-exposure to the smoke. The results from the field studies showed that five coil formulations are effective in repelling mosquitoes for 6 hours, with low to average smoke visibility, good- satisfactory odour, and no irritability. From the laboratory studies, the same coil formulations could be identified as having fast mean knock-down times and higher 24-hour post-mortality values above 80%. Therefore, through this study, it can be concluded that these coil formulations with neem: *maduruthala*: betel: citronella: cinnamon ratios, respectively, 1:3:1:1:1, 1:1:3:1:1, 1:1:1:3:1, and 1:1:1:1:3 are more efficient in repelling mosquitoes compared to other formulations and the plant materials used in this study have components capable of repelling mosquitoes individually or collaboratively. Further laboratory studies and field studies of a larger study population at different geographical locations with a higher number of replicates are required for the commercialization of these mosquito coil formulations as herbal mosquito repellents.

Keywords: *Aedes aegypti*, Bio-efficacy-testing, Herbal-plants, Mosquito-coil, Natural-repellents,