Development of a Pheromone Based Smart Mosquito Trap

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Abstract. This research aimed to develop a pheromone-based smart mosquito trap for reducing the regional and temporal occurrences of mosquito-transmitted pathogens. The study was mainly concerned with killing mosquitos in a very large area without negatively impacting the physical health of living beings. The device was constructed from a 5 mm thick acrylic sheet and includes several mosquito-attracting elements, including a heating pad, UV light, CO_2 cylinder, and various pheromones. An exhaust fan and reservoir of sticky substance were used to trap and kill the mosquitos. The CO_2 dispersion and exhaust fan were regulated with time intervals and a controller while other components were in fixed operative mode. Four different pheromone formulationswere prepared and usedin different ratios with varied ranges of reagentsand natural products such as Cyclopentanone, Palmitic Acid, Oleic Acid, Linoleic Acid, Citric Acid, and-Mushroom Extracts (Shiitake Mushroom & Reishi Mushroom). For successive efficiency and performance test, the device was kept in trial for 8 days, and each day, a different kind of pheromone formulation with varying amounts and without $CO_2$was used at different areas.The trial showed excellent results by trapping and killing an abundant quantity of mosquitos both in indoor and outdoor operations. In the future, the device will be modified to make it easier to operate by producing all in one solution which will be used in-house as well as in a large open area with solar power. Such a device could be the best choice to kill mosquitos in countries like Bangladesh where mosquito-borne diseases are great concern during a specific season every year.

Keywords: Mosquito Trap · Mosquito · Pathogens · Pheromone

1 Introduction

Mosquitos are a significant public health concern in south-east Asian countries like Bangladesh, posing a threat by transmitting various diseases such as malaria, dengue, and Zika etc. According to the World Health Organization (WHO) reports, mosquito-borne diseases take the life of some 725,000 peoplein a year globally where malaria

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alone accounts for 600,000 people. Traditional mosquito control methods, such as the use of insecticides and mosquito nets play a role in reducing mosquito populations and controlling the spread of diseases. However, these methods are often ineffective, and expensive with negative environmental impacts. Thus, the development of a smart mosquito trap would be an alternative solution. Such eco-friendly devices use advanced technology to attract and trap mosquitos in an effective way than the traditional methods. Mosquitos are attracted to various stimuli, including carbon dioxide, heat, chemical compounds, dark colors, etc. which can be used to craftan artificial environment like human and other animals' exhalation. This research aimed to use various pheromones such as cyclopentanone which attracts mosquitos, particularly the Aedes aegypti mosquito species responsible for spreading Dengue fever, Zika virus, and Chikungunya. UV light usually uses to attract different kinds of insects including mosquitos. In addition, Carbon Dioxide (CO_2) gas present in human and animal exhalation is considered an important component for attracting mosquitos. Thus, the device was designed by combining all these mosquito attractants CO_2, pheromones, UV light, and heat, and targeted to use in huge outdoor areas as well as in-house.

1.1 Existing Devices and Related Works

Some existing devices were found as mosquito trap with some limitations. These devices were built intelligently using carbon dioxide (CO_2), ultraviolet (UV) light, or a combination of both to kill several hundreds to thousands of mosquitos on regular basis. According to a study published in the Journal of Medical Entomology CO_2 gas was used in a mosquito trap but that was found expensive with laborious maintenance procedure [1]. The CDC Autocidal Gravid Ovitrap (AGO) installed a device for killing mosquito larvae and eggs at different locations. Their study reported the use of CO_2 gas as an effective attractant for the Aedes aegypti mosquitos, and lowered the mosquito population responsible for both Dengue and Zika [2]. Ultraviolet (UV) emitting devices were used in some devices to trap mosquitos but the study found as the technology was expensive with difficult maintenance [3]. In another study, the mosquito killer lamp was used together with electrodes to attract and kill mosquitos but the gadget was effective only in small places having limited space inside it [4]. Some researchers used devices combing both CO_2gas and UV light to lure mosquitos into a trap and get killed. However, the study also found that the device was expensive and required maintenance [5].

2 Materials and Equipment

Very simple and readily available materials such as acrylic sheet, glue, exhaust fan, twin timer, cable, indicator lamp, switch, connector, digital display thermostat temperature controller (W1219), adapter, aluminum L angle, 6 core wire, pipe air, 8-pin base, plug, adipic acid, barium hydroxide, UV light, heating pad, CO_2 gas, solenoidregulator, vinyl sticker, shiitake mushroom, reishi mushroom, ethanol, palmitic acid, oleic acid, and linoleic acid etc. were used to develop the smart mosquito trap.Various equipment such as a laser cutter, drilling machine, incubator, digital weight machine, fumehood, oven, drill machine, refractometer, and FTIR machine were used.

3 Methods

3.1 The Device Development Process

1. Atfirst, different parts of the device were designed using solidworks and sketches were done on the front plane, top plane, and right plane according to the position of the parts. Then extruder and cutting tools were used.
2. Then the solidworks files were converted into a DXF file and PNG file with accurate measurements and later the laser cutting was performed on a 5 mm acrylic sheet.
3. At this stage, the device was given a final appearance by assembling both the lower and upper parts and fixed with glue.
4. After completion of the outside structure, main components like the fan, heating pad, temperature control module, and UV light were attached and wrapped properly inside the device. The fan was attached to the top in such a way that it could pull the mosquitos inside. W1219 temperature controller was used to regulate the device temperature at 37 °C to feel like human body temperature.
5. All the wires of the components were arranged serially and connected to a 6-core wire by isolating with a thick paper sheet.
6. The control box was designed in Solid works and then the final circuit was preparedand fitted inside the control box. Two twin timers, two LED indicators, and the switchboard was attached to the control box. One of the twin timers was connected to the fan and the other one was connected to the CO_2. One of the LED indicators was for indicating the run time of the CO_2 while another one was for indicating the run time of the fan. Finally, 4 switches were placed to regulate the supply of CO_2, fan, heating pad, and UV light separately as shown in Fig. 1.
7. A CO_2 cylinder was attached outside the device and CO_2 pressure was set at 6MPa.
8. Finally, the paper cover of the acrylic sheet was pulled off and the whole device was wrapped in a black vinyl sticker for providing the dark environment to attract mosquitos.
9. Lastly, a sticky trap was prepared using a thick solution of water and sugar, liquid soap, and few drops of pheromone (Fig. 2).

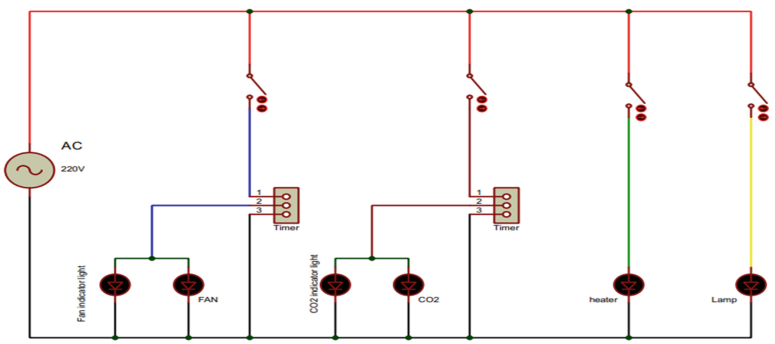

Fig. 1. Circuit Design of the Control Box

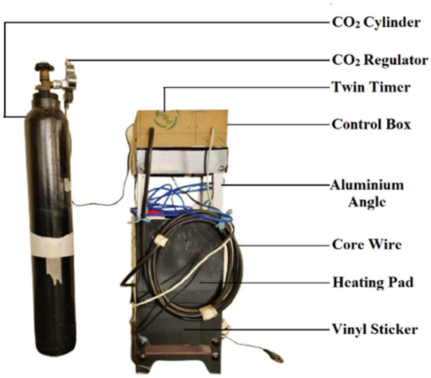

Fig. 2. Smart Mosquito Trapping Device

3.2 Preparation of Pheromone

Four different types of pheromone formulations were prepared by adding different compounds in Cyclopentanone as follows:

Preparation of Pheromone Formulation 1: Cyclopentanone was prepared by dry distillation of 20 g of adipic acid and 2 g of barium hydroxidesolution at 295 °C. Cyclopentanone is a colorless volatile liquid and toxic with an unpleasant smell [6]. Initially, the round bottom flask was charged with these compounds and set it up for distillation. A dry distillation without the oil bath is the best procedure. When the reactor temperature reached at 100 °C the reflux condition was achieved and waited to raise the temperature to 200 °C and the reaction continued for several hours with distillation and collection of the cyclopentanone in a receiving flask through condensation. The organic layer was collected by removing the water part using a separatory funnel. Then it was dried by adding anhydrous potassium carbonate and filtered it. The second round of the same distillation procedure was repeated and impurities were removed and pure cyclopentanone was collected.

Preparation of Pheromone Formulation 2: In this formulation, cyclopentanone was mixed with palmitic acid, oleic acid, linoleic acid & citric acid. The pheromone formulation 2 was prepared following the same reaction condition used in pheromone formulation 1.

Preparation of Pheromone Formulation 3: For this formulation, 2 types of mushroom (Shiitake & Reishi) extracts were used. Shiitake and Reishi mushroom extracts were started by boiling these in hot water and then the organic phase was collected. At first high-quality Shiitake and Reishi mushrooms were brought and rinsed under cold water to remove any dirt or debris. Then cut it into small pieces or slices to increase the surface area while boiling. Water was boiled in a pot and the mushroom pieces were added to the boiling water. The heat was reduced and the mushrooms were simmered in the water for at least 30 min. After simmering, the pot was removed from the heat, and the liquid was strained through a fine-mesh sieve or cheesecloth. The extracted liquid was poured into a round bottom flask and stored in the fridge for up to 1 week. The stored extract was dissolved in Ethanol at 80 °C and then mixed with formulation 2 to prepare pheromone formulation 3.

Preparation of Pheromone Formulation 4: Here, only 2 types of mushroom extracts (Shiitake & Reishi) were dissolved in Ethanol at 80 °C. The rest of the procedure is the same as the procedure of pheromone formulation 3. The pheromone formulations were diluted by mixing 0.5 ml pheromone with 50 ml ethanol each. The target was to dilute the pheromone to spread these more easily while used in the developed smart mosquito trap.

4 Test and Trial

Fourier Transform Infrared Spectroscopy (FTIR) was used to analyze and investigate the prepared pheromone formulations. The pheromone formulation was mixed with KBr powder, made into a transparent disc using a pellet-making machine, and then placed into the IR beam, and data was recorded separately.

The device was built based on easy to operate principle. At first, the switches of the UV lamp and heating pad were turned on. The heating pad's temperature is set to 37 °C by default. After a certain time, the CO_2switchwas turned on, and then after waiting for another few minutes the fan switch was turned on as the CO_2 needed to be spread properly in the surrounding air, and the fan started to pull the mosquitos inside it. At different days, 4 different types of pheromone formulations were used to see the result for attracting mosquitos. Once the fan pulled the mosquitos inside the device, they were trapped in the sticky liquid and got killed.The trials were run overnight and dead mosquitos were found in the sticky trap in the morning. Then the sticky trap was disposed of completely along with the dead mosquitos.It was trialled for a total of 8 days with 4 types of pheromone formulations with or without the supply of CO_2.

5 Result & Discussion

FTIR results for the pheromone formulation is shown in Fig. 3.

Cyclopentanone is a cyclic ketone with a distinctive carbonyl stretch in the FTIR spectrum. Usually, the carbonyl stretch occurs between 1700 and 1750 cm^{-1}. Furthermore, cyclopentanone exhibits C-H stretching vibrations between 2900 and 3000 cm^{-1}.

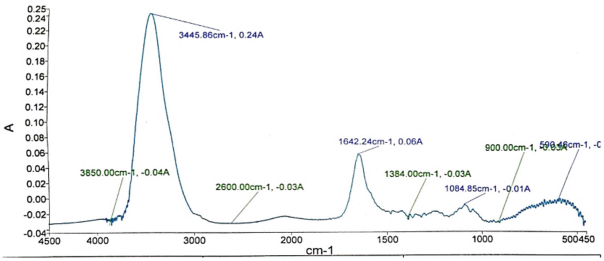

Fig. 3. FTIR spectrum of pheromone formulation

The C = C stretching vibration at roughly 1600 cm^{-1} and the C-C stretching vibration at roughly 1100 cm^{-1} are additional significant peaks in the FTIR spectra of cyclopentanone. These peaks provide evidence that the molecule has a cycloalkane ring. The circumstances of the sample, such as its concentration, temperature, and solvent, can change the FTIR spectrum of cyclopentanone. To get accurate and repeatable FTIR spectra, it was crucial to carefully control the experimental conditions.

Trial Result of the Device: The trial period consisted of 8 days. Each formulation was used for two trial days respectively with and without CO_2. The run time was 12 h per day. The trial result for a total of 8 days is given in Table 1.

This work aimed to develop a pheromone-based smart mosquito trap for reducing the regional and temporal occurrences of mosquito-transmitted pathogens. The study was mainly concerned with killing mosquitos in a very large outdoor area without negatively impacting the physical health of living beings. The device was tested for a total of 8 days, with each day using a new pheromone composition with and without CO_2. From the trial result, the maximum numbers of trapped mosquitos were achieved using the pheromone formulation 3 & the numbers were 574 (with CO_2) & 416 (without CO_2). Pheromone formulation 3. On the other hand, the least number of mosquitos were trapped using pheromone formulation 4 & the number was 126. Pheromone formulation 4 is made only

Table 1. Result of the total 8 Days of Trial

Day	Pheromone Formulation No	Run Time (Hour)	With/Without CO_2	Number of Trapped Mosquitos
1	1	12	With CO_2	374
2	1	12	Without CO_2	128
3	2	12	With CO_2	243
4	2	12	Without CO_2	182
5	3	12	With CO_2	574
6	3	12	Without CO_2	416
7	4	12	With CO_2	180
8	4	12	Without CO_2	126

Fig. 4. Trapped Mosquitos by Pheromone Formulation 3

from the extract of mushrooms. The number of mosquitos trapped using formulation 1 was also very low which is 128. By using the rest of the pheromone formulations (1 & 2) moderate numbers of mosquitos were trapped (with & without CO_2) (Fig. 4).

The device can run automatically once it is turned on and set up according to the user's requirements. The integrated circuits were used to make the device as smart mosquito trap. Furthermore, other modifications can be done to the device in future such as use of PCB and solar power. By this way the device will be developed and marketed as less expensive and in more user friendly manner for both indoor and outdoor use.

6 Conclusion

The ultimate goal of this research was to trap a large number of mosquitos in open and wide areas and it was mainly achieved through the use of pheromone formulation 3. The leading function was performed by the pheromone and other components such as CO_2, UV light, and heating pad contributed to luring mosquitos towards the device and trapping them inside and got killed. This device can reduce the spread of mosquito-borne diseases by killing more than several hundred mosquitos on a regular basis. It can also be considered green technology as no harmful chemicals were used in this device which poses threat to the environment as well as to living beings. More research should be conducted in the near future to ensure the vast and regular use of such smart mosquito traps to kill huge quantities of mosquitos both in indoor and large outdoor areas.

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Conflict of Interest. The Authors declare that they have no conflict of interest.

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