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Mosquito trap prototypes for low−resource settings: A comparative study

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ABSTRACT

Objective: To develop mosquito trap prototypes and compare their efficiency and cost-effectiveness with commercial products.

Methods: The frameworks for mosquito trap prototypes were separately developed and assembled. The warmth retention efficiency and duration of carbon dioxide (up to 400 ppm) release were determined for the prototypes. Mosquito trap efficiency was determined by comparing the number of mosquitoes trapped in sticky glue only, mosquito trap prototypes I, II, and III, and commercial products I, II. A comparative analysis of cost, durability, availability, power consumption and effectiveness was also performed. Results are expressed as mean±standard deviation. A $P<0.05$ was considered statistically significant.

Results: Mosquito trap prototypes I, II and III were successfully developed. The warmth retention and carbon dioxide release (up to 400 ppm) were sustained for about two hours after the assembly of the prototypes. Mosquito trap experiments demonstrated significantly higher mosquito trap efficiency for mosquito trap prototype III, with 6.3±3.1 mosquito trapped using citric acid:sodium bicarbonate (1:2) and 4.6±2.1 mosquito trapped using citric acid:sodium bicarbonate (1:1). No mosquitoes were trapped in both commercial mosquito traps. Furthermore, commercial mosquito traps were expensive, had uncertain durability, longer access times after ordering, and required a continuous power supply. In contrast, the developed mosquito trap prototype III was cheap, easy to handle, durable, easily available, required low power consumption and highly effective in trapping mosquitoes.

Conclusions: Mosquito trap prototype III provides an economical and viable solution for trapping mosquitoes, mainly for low-income populations.

KEYWORDS: Carbon dioxide; Mosquito trap prototype; Vector-borne disease

1. Introduction

Mosquito-borne diseases (*e.g.*, dengue, malaria, yellow fever, Chikungunya, Japanese encephalitis and West Nile) are highly prevalent worldwide leading to greater health risks resulting in deaths and considerable economic burden[1]. Summer season, with extreme precipitation and increased temperature, provides favorable condition for abundant population growth of mosquitoes[2] which is valid also in the case of Nepal. A burning issue, of climate change, also has greatly impacted on the rapid growth of mosquito population resulting in their wider distributions, even to higher altitudes[3]. Such an abundant mosquito population is responsible for mosquito bites, which could result in mosquito bite borne diseases. Therefore, killing or trapping and surveillance of mosquitoes is crucial to prevent the occurrence of such diseases.

Significance

Mosquito-borne diseases remain a significant global health challenge, posing serious risks to human well-being. The lack of accessible and affordable mosquito traps exacerbates this issue, particularly in low-resource settings. This study aimed to develop and evaluate mosquito trap prototypes in comparison to existing commercial products. Among the three prototypes developed, prototype III demonstrated the most effective mosquito trapping performance while remaining cost-effective and practical, making it especially suitable for low-income communities.

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According to the World Health Organization (WHO), in 2020, an estimated 241 million cases and 627 000 malaria deaths were reported worldwide[4]. There was an increase in 14 million malaria cases and 69 000 deaths in 2020 as compared to 2019. Similarly, the incidence of dengue has grown dramatically in recent decades. Since the beginning of 2023, the world has been facing an upsurge or dengue cases and deaths reported in endemic areas with further spread to areas previously free of dengue[5]. Furthermore, a modeling estimate indicates 390 million dengue infections[6] whereas other study estimates 3.9 billion people being at risk of dengue infection[7]. This data represents the increasing trend of vector-borne diseases such as malaria and dengue worldwide.

Protection from mosquito bites is a viable strategy in the prevention of mosquito annoyance, itching and the development of vector-borne diseases. Reducing the mosquito population would be a viable approach to control mosquito bite borne diseases[8]. However, it is difficult to reduce the population as mosquitoes can readily grow in different conditions/areas of dampness and darkness. Therefore, alternative strategies including insecticide-treated nets and indoor spraying have been used[9–11]. Additionally, a variety of commercial mosquito repellents (*e.g.*, vaporizers, mats, coils and personal use creams, roll-ons, and sprays) are being used for the prevention of mosquito bites[12]. The efficacy of such alternative strategies is still limited as mosquitoes are being adaptive to the strategies and also the mechanism of action of mosquito repellents are limited to a shorter period of time. Furthermore, short or long-term exposure to chemicals and insecticides, used as mosquito repellents, can be harmful to humans. Therefore, an alternative strategy that could kill mosquitoes without the use of any chemicals or insecticides would be preferable[13].

In Nepal, individuals outside the protection of bed nets remain highly susceptible to mosquito bites. While mosquito repellents, such as smoke from burning wood or certain plants, are also used, their effectiveness is limited, and they provide only short-term protection[14]. Therefore, to enhance mosquito control, effective mosquito traps are essential.

Female mosquitoes rely on a combination of chemical and physical cues to locate their hosts, including carbon dioxide, heat, body odor, moisture, and visual contrast[15]. Across various mosquito species, carbon dioxide triggers a range of context-dependent responses that stimulate host-seeking behavior by activating specialized carbon dioxide-detecting neurons[16]. Heat further attracts mosquitoes at close range, prompting them to land on objects mimicking human body temperature, especially in the presence of carbon dioxide[17]. Therefore, mosquitoes primarily locate and bite humans by detecting carbon dioxide emissions and body heat, making these factors essential in designing effective traps. To orient towards hosts, female mosquitoes detect a variety of chemical and physical cues including body odor, carbon dioxide, moisture, heat, and visual contrast. In a broad range of mosquito species, carbon dioxide elicits a suite of context-dependent effects that are thought to promote host-seeking behavior via activation of carbon dioxide-detecting neurons. Heat attracts mosquitoes to their hosts at close range and mosquitoes will land on inanimate objects set at human body temperature in the presence of carbon dioxide. Hence, mosquitoes locate and bite humans by detecting carbon dioxide emissions and body heat, making these factors crucial in designing efficient traps[18].

Mosquito traps are a useful tool for trapping the mosquitoes thus preventing them from biting humans, but it is not feasible and user friendly all the time. Furthermore, multiple parameters like external environmental factors, the number of traps needed to cover a specific area, trapping duration, and mosquito capture rates affect the mosquito trap efficiency. Under this context, research is envisioned with the specific objective to develop mosquito trap prototypes to enhance capture rates and compare them with other commonly available commercial products in Nepal. The use of natural attractants like heat and carbon dioxide in the developed prototypes make them a suitable attractant for trapping *Anopheles* mosquitoes. Additionally, the developed mosquito trap prototype is cost-effective and have potential practical applications in low-income population of Nepal.

2. Methods

2.1. Materials

Materials required for the project included iron for metal framework, sodium bicarbonate (Nike Chemical, India), citric acid (Nike Chemical, India), distilled water, sticky glue (Daraz, Nepal), and electric heating pad (Daraz, Nepal).

2.2. Instruments/Machines

Instruments/machines for the research project included CNC Lathe (GSK CNC Equipment Co., Ltd, China), bending machine (Yawei Machine-Tool Group Company of Jiangsu, China), carbon dioxide sensor (AZ Instrument Corp., Taiwan), mosquito counter (Daraz, Nepal), and commercially available mosquito traps [Commercial mosquito trap I (Lightning mosquito lamp, China) and Commercial mosquito trap II (Photocatalysis suction type mosquito killer, China)].

2.3. Metal framework and prototype development for mosquito traps

Different parts of the mosquito trap were prepared separately and assembled to develop the final prototype. The parts included: 1) Open framework with a holder; 2) Plastic container to hold sodium bicarbonate, citric acid and water to produce carbon dioxide which can be directed to the surface of prototype via tubing; 3) A heating pad/hot water tank placed above the carbon dioxide generation

chamber; and 4) A sticky glue paper placed on top of the heating pad. Three different prototypes of mosquito traps were prepared for the study as mosquito trap prototype I, mosquito trap prototype II, and mosquito trap prototype III. Mosquito trap prototype I, II and III are of small, medium and large category, respectively with individual surface areas of 43 cm^2, 87 cm^2 and 481 cm^2 for trapping the mosquitoes. Mosquito trap I and II used hot water as a source of heat whereas mosquito trap III used electric heating pad as the source of heat. All three mosquito trap prototypes used separately weighed sodium bicarbonate and citric acid mixed in distilled water for the generation of carbon dioxide. The total weights of sodium bicarbonate and citric acid (at ratios of 2:1 and 1:1) used per prototype were 5 g (in 50 mL), 30 g (in 300 mL) and 30 g (in 300 mL), respectively for mosquito trap prototypes I, II, and III. Furthermore, commercial sticky paper of different sizes were used (*i.e.*, $1/8^{th}$, $1/4^{th}$ and whole paper) for mosquito trap prototypes I, II, and III, respectively.

2.4. Evaluation of carbon dioxide generation and release through the nozzle

The amount of carbon dioxide generated by reacting sodium bicarbonate with citric acid in water was evaluated using a carbon dioxide sensor. Afterwards, at different time points, the generated carbon dioxide was tested through the nozzle to assess the duration of carbon dioxide release above 400 ppm, which can be sensed by the mosquitoes since the carbon dioxide level was approximately 400 ppm in the open space of our study.

2.5. Determining maintenance duration of warmth in hot water container and heating pad for mosquito prototypes

Warm distilled water was added to the water containers of mosquito trap prototype I and II, and the system temperature was measured. Similarly, an electric heating pad was heated, assembled onto mosquito trap prototype III, and the system temperature was measured to evaluate if the warmth was maintained to attract the mosquitoes.

2.6. Comparison of the developed mosquito trap prototype with commercial products

A comparative analysis of the effectiveness of the developed prototype, compared with commercial products, was performed by counting the mean number of mosquitoes trapped by each product during a 3 h trap period for three consecutive days in July 2024. The developed mosquito trap prototypes work on the principle of luring mosquitoes by using heat and carbon dioxide. Two commercial mosquito traps were used for comparison with the developed prototypes, based on their availability in the market. No commercial mosquito traps with heat or carbon dioxide were available for purchase. Therefore, the available products, Commercial mosquito trap I (Lightning mosquito lamp; product model: JT-Z01; Made in China) and Commercial mosquito trap II (Photocatalysis suction type mosquito killer; product model: BG-360; Made in China) were used for mosquito trap comparisons with the developed prototypes. Both of these products work on the principle of luring mosquitoes using blue light and sucking the mosquitoes in using a wind turbine. Although the mechanisms of commercial mosquito traps are different, these two products are the only mosquito traps available commercially and hence were used for comparison with our developed mosquito trap prototypes.

The study site for mosquito traps was household in Pokhara Metropolitan City, Kaski, Nepal with their placement close to the doors (*i.e.*, shaded area) at a height of 3 feet (outdoor) and 10 feet apart. The outdoor temperature during the study period was 33±1.5 ºC with a humidity of 75±5% and wind speeds below 2 km/h. The prototypes and commercial products were placed adjacent to each other and the placements were altered during different days of the study period. Sticky glue was used as a control. The timing for mosquito trap was 5 pm-8 pm local time as the number of active mosquitoes increase during this period. The trap efficiency was determined for a 24 h period as well. The trapped mosquitoes were then identified based on their color, palp and wings. *Anopheles* mosquitoes were identified as brownish in color with long palps and spotted wings that are active at dusk. The trapped *Anopheles* mosquitoes were then counted. Furthermore, a comparative analysis of cost, energy consumption and durability were performed to determine the economic aspects.

2.7. Data analysis

Microsoft Excel was used to perform data analysis and graph preparations. Values are represented as mean ± standard deviation. Student's *t*-test was performed to determine the level of significance and $P<0.05$ was considered statistically significant. The analyzed data are summarized into suitable tables and graphs.

2.8. Ethical statement

This study did not involve human participants or vertebrate animals. All mosquito collections complied with local environmental and public health regulations.

3. Results

As per the objective of the study, prototype development of mosquito trap was conducted. Initially, the objective was to develop a single prototype; however, it was realized that the different sizes of mosquito traps need to be developed and compared. Therefore, a total of three different mosquito trap prototypes I, II, and III with respective small (43 cm^2), medium (87 cm^2) and large surface areas (481 cm^2) were developed (Supplementary Figure 1).

For carbon dioxide generation, a simple reaction between sodium bicarbonate and citric acid was carried out in the presence of water. The carbon dioxide thus formed was collected in the tight chamber and passed through the nozzle. Mosquitoes detect carbon dioxide levels above 400 ppm to locate humans, as the baseline carbon dioxide level in open spaces was approximately 400 ppm. Therefore, the time frame for which the carbon dioxide levels (≥400 ppm) are maintained in the mosquito trap prototypes were determined. Results showed that the ratio of citric acid and sodium bicarbonate influenced the concentration of produced carbon dioxide. A ratio of citric acid:sodium bicarbonate (1:2) was able to maintain the desired carbon dioxide levels for more than one and a half hours (Figure 1A) whereas a ratio of 1:1 maintained desired carbon dioxide levels for more than one hour (Figure 1B).

Furthermore, in prototypes I and II, hot water tanks (100 mL and 150 mL capacity, respectively) were used to retain warmth for the trap which differed in volumes whereas for prototype III, a heating pad was used. The duration of warmth retention after adding hot water to the prototypes I and II, and after heating the pad for prototype III was determined. The temperature control effects of different prototypes were determined (Figure 1C, 1D and 1E). Results suggest that with the addition of warm water to the water tanks in mosquito trap prototypes I and II, the temperature around 30 ºC can be maintained for 2 h. Similarly, the electric heating pad temperature in mosquito trap prototype III could also be maintained for the comparable time period.

Two commercial products were purchased for comparison of the mosquito trap efficiency with the developed prototypes. The commercial products are presented in Supplementary Figure 2. Mechanism of mosquito trap of these commercial products is different from what has been proposed for our developed prototypes (*i.e.*, warmth and carbon dioxide). Few commercial products were available previously with similar mechanisms of mosquito trap to that of our developed prototypes; however, their supply has been discontinued recently. Commercial mosquito traps I and II work on the principle of suction by air current from fans, wherein mosquitoes are lured by blue light and collected in a container where they get killed.

A combination effect of the temperature and carbon dioxide along with the black colored framework was assessed for mosquito trap efficiency of the developed and optimized prototypes which were compared with that of the commercial products (Supplementary Figure 3 and Figure 2). Two different ratios of citric acid: sodium bicarbonate *i.e.*, 1:2 and 1:1 were used for the comparison of carbon dioxide generation and subsequent mosquito trap efficiencies. As a control, when only sticky glue was used, the number of mosquitoes

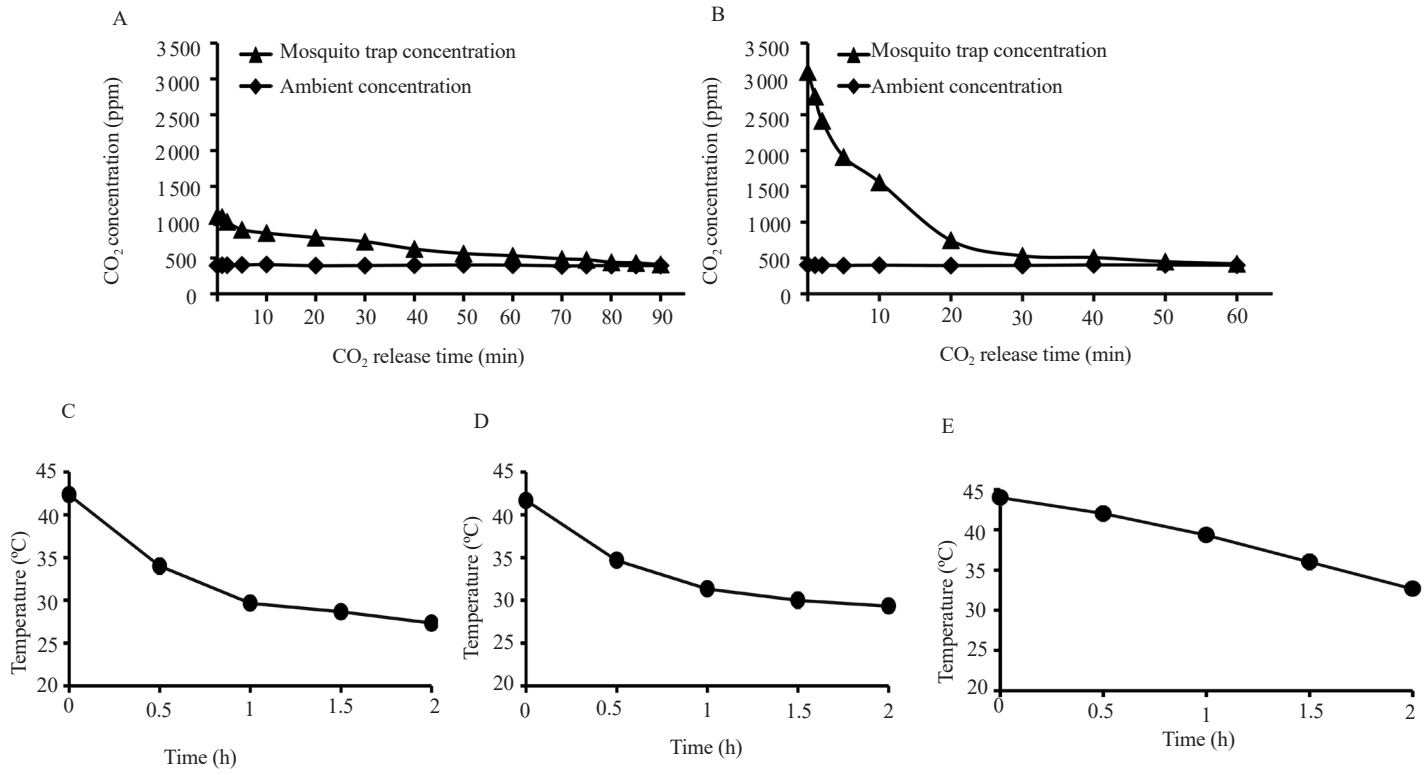


Figure 1. Carbon dioxide generation time frame for A (1:2 citric acid:sodium bicarbonate) and B (1:1 citric acid:sodium bicarbonate); Temperature control effects of mosquito trap prototypes: Prototype I (C), Prototype II (D) and Prototype III (E) up to 2 h. Measurements were performed in triplicate, with surface temperature of the tank or heating pad recorded using a temperature gun.

trapped during a 3 h trap period were minimal (0.67±0.58). As compared to the citric acid:sodium bicarbonate ratio of 1:1, the ratio of 1:2 showed higher mosquito trap efficiency [mosquito traps for 1:1 ratio – prototype I (0.33±0.58), prototype II (1.33±1.53), and prototype III (4.67±2.10, P<0.05 as compared to control); mosquito traps for 1:2 ratio – prototype I (1.33±0.58), prototype II (2.00±1.00) and prototype III (6.33±3.10, P<0.05 as compared to control)]. Among the prototypes, mosquito trap prototype III only exhibited significantly higher number of mosquito traps as compared to control. Interestingly, there were no mosquitoes trapped for both commercial mosquito traps (I and II). The trapped mosquitoes were *Anopheles*. During the 24 h trap period, non-mosquito collections were also observed. The common non-mosquito collections included ants, moth flies and small grasshoppers. There was no significant difference in the mosquito trap efficiency between 3 h and 24 h trap periods. Therefore, a 3 h trap period was used for comparison which also reduced the trapping of other non-mosquito insects.

The durability, cost, and power consumption of developed mosquito trap prototypes are presented in Table 1. The developed mosquito trap prototypes have a higher durability of 5 years or more. Only mosquito trap prototype III requires 5 W power consumption for heating the pad. The cost of mosquito trap prototypes I, II, and III are $4.03, $4.18 and $5.92, respectively. The cost of consumables (citric acid, sodium bicarbonate, sticky paper) for first use are $0.08, $0.22, and $0.63, respectively for mosquito trap prototypes I, II, and III. Furthermore, the cost of consumables per day for subsequent use for further 15 days are $0.02, $0.08 and $0.08, respectively.

Similarly, the comparison of cost, durability, availability, power consumption and effectiveness of commercial and developed mosquito trap prototypes is presented in Table 2. Commercial mosquito traps I and II cost $5.97 and $10.14, respectively. They both require 5 W continuous electricity supply for operation. Their durability is uncertain and it takes time to be delivered once ordered. Furthermore, they were ineffective in trapping mosquitoes. Our developed mosquito trap prototypes are durable, require no or minimal power consumption. Regarding mosquito trap efficiency, mosquito trap prototype I is less effective, mosquito trap prototype II is effective, and mosquito trap prototype III is highly effective.

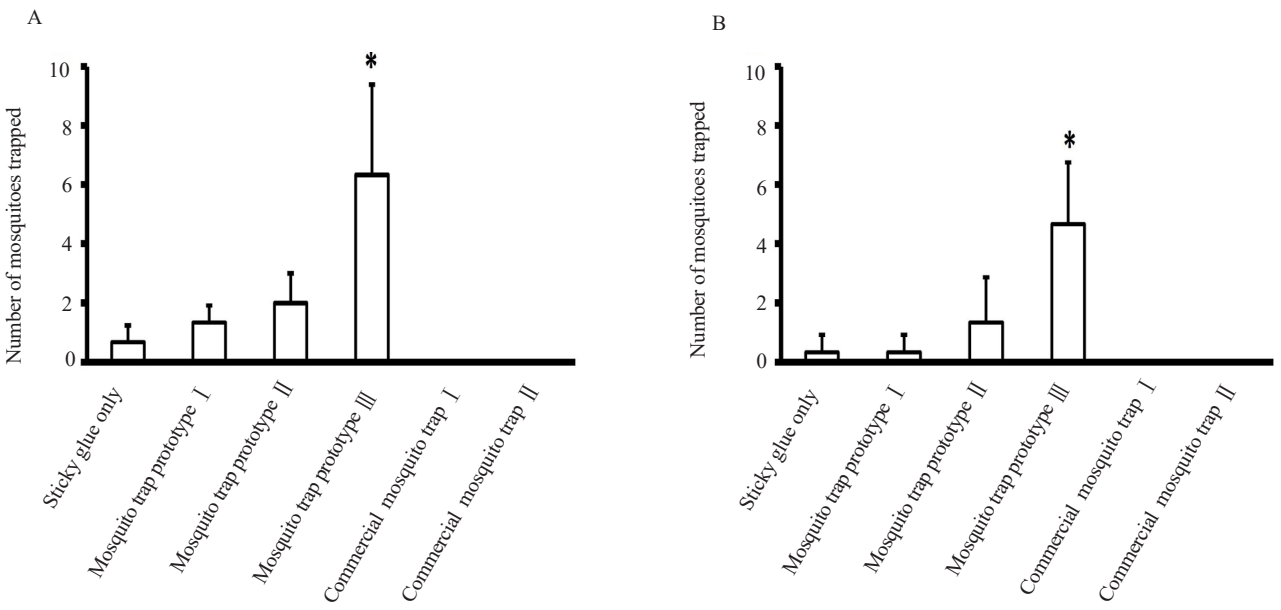


Figure 2. Comparison of the mosquitoes trapped for A (1:2 citric acid:sodium bicarbonate), and B (1:1 citric acid:sodium bicarbonate) by different mosquito trap types. *P<0.05.

Table 1. Durability, cost, and power consumption of the developed mosquito trap prototypes.

Product Name	Durability	Power consumption	Cost in NPR(USD)	Consumables cost in NPR(USD)#	Daily consumables cost in NPR(USD)#
Mosquito trap prototype I	5 years	0	540 (4.03)	11.25 (0.08)	2.25 (0.02)
Mosquito trap prototype II	5 years	0	560 (4.18)	29 (0.11)	11 (0.08)
Mosquito trap prototype III	5 years	5 W (no continuous power needed)	793 (5.92)	84 (0.63)	11 (0.08)

Note: #Exchange rate: 1 USD=134 NPR.

Table 2. Comparison of cost, durability, availability, power consumption, and effectiveness of commercial *vs*. prototype mosquito traps.

Type of product	Cost in NPR (USD)	Durability	Availability	Power consumption	Effectiveness (number of mosquitoes trapped)
Commercial mosquito trap I	800 (5.97)	Uncertain	Takes time to be delivered	5 W (no continuous power needed)	0
Commercial mosquito trap II	1359 (10.14)	Uncertain	Takes time to be delivered	5 W (no continuous power needed)	0
Mosquito trap prototype I	540 (4.03)	Minimum of 5 years	Easier availability	No power required	1.33±0.58
Mosquito trap prototype II	560 (4.18)	Minimum of 5 years	Easier availability	No power required	2.00±1.00
Mosquito trap prototype III	793 (5.92)	Minimum of 5 years	Easier availability	5 W (no continuous power needed)	6.33±3.06

4. Discussion

The mechanism of sensing and bite to humans by the mosquitoes includes the use of carbon dioxide and body warmth released from human body[15]. Therefore, mosquito traps that include both carbon dioxide and warm temperature would be effective in attracting the mosquitoes that could then be trapped[19]. We developed such mosquito trap prototypes in this study. A study was performed previously to develop a more effective mosquito trapping box for vector control. It was found that mosquito trapping boxes were effective when more factors were added, however, significant differences were observed only for cotton cloth and carbon dioxide additions[20]. Effective mosquito trap strategy could thus involve the use of carbon dioxide and warmth.

In our study, we used carbon dioxide concentrations of over 400 ppm to attract mosquitoes, as ambient carbon dioxide levels in open spaces were approximately 400 ppm. The reaction between citric acid and sodium bicarbonate led to the production of carbon dioxide which was directed to the surface of mosquito trap for attracting the mosquitoes. In a study by Li *et al*., human metabolic emissions of carbon dioxide and their implications for carbon emissions were determined. An increase in whole-body carbon dioxide emissions was observed with an increase in temperature. Whole body carbon dioxide emission rate was determined to range from 29.7-32.1 g/h/person, suggesting higher carbon dioxide emissions by humans[21]. In a study by McPhatter and Gerry (2017), the effect of carbon dioxide concentration on mosquito collection rate using odor-baited suction traps was determined. A total of six carbon dioxide release rates ranging from 0-1 495 mL/min were used in capturing the mosquitoes. Increasing carbon dioxide release rates resulted in an increase in the number of individual females captured[22]. Similar research was performed for an eco-friendly mosquito control by using a new mosquito trap in a cowshed in Yeoju, Republic of Korea[23]. This study determined that higher emission rates of carbon dioxide significantly increased the numbers of mosquitoes trapped. In our study, the rates were not altered as it was automatically altered due to variations in reaction rates and subsequent release of produced carbon dioxide from the chamber. Such devices have great importance for the prevention of mosquito bites and disease control not only for humans but also for animals, especially those being raised in animal farms.

In our study, warm water or heating pad were used as a source of heat for the mosquito trap prototypes. The warmth was maintained for at least a period of two hours. Warmth is necessary to mimic the body conditions to attract the mosquitoes. A study was performed to determine the effect of heat and humidity on improving the performance of an odor-baited trap. Results suggested that the inclusion of heat and humidity doubled the number of mosquitoes captured by odor-baited trap attributed to their ability to lure more mosquitoes close to the trap and retain them longer[19]. Therefore, use of heat that mimics body temperature would be suitable to enhance the mosquito trap rates, and this strategy was used for our developed mosquito trap prototypes. A similar study investigated how the combination of carbon dioxide, heat, black color, humidity and attractants influenced mosquito trap rates using a field trapping device[24]. Conducted in an open space, the study concluded that both heat and carbon dioxide are essential for attracting and capturing mosquitoes. While female mosquitoes were able to visually detect black objects and humidification around the heat source potentially increased their detection range, it did not significantly impact mosquito landing behavior. Ultimately, the study highlighted that carbon dioxide and heat play a pivotal role in mosquito attraction, whereas odorants, humidity, and black color have a comparatively lesser effect[24]. A higher number of mosquitoes were trapped in this study compared to ours, likely due to the difference in trapping durations – 12 h *vs*. just 3 h in our study.

In our study, different types of mosquito traps have been developed and compared for their efficacy with commercial mosquito traps. Compared to commercial mosquito traps, the developed mosquito trap prototypes exhibited better mosquito trapping efficiency. Notably, mosquito trap prototype III showed significantly higher mosquito traps as compared to control. Also, the developed mosquito trap prototype III is durable and cost-effective as compared to commercial products. A similar comparison of the performance of different mosquito traps was assessed in Papua New Guinea[25]. Three devices: the Centers for Disease Control and Prevention light trap with incandescent light (CDC_I), the CDC light trap with ultraviolet light (CDC_UV), and the biogents-sentinel (BG) trap were used to identify a suitable and cost-effective surveillance tool. Of the total mosquitoes collected, CDC_I caught 7.9%, BG caught 14.5%, and CDC_UV caught 77.6% mosquitoes. Similarly, in another study, field evaluation of commonly used adult mosquito traps in Greece

was performed using different kinds of mosquito traps *i.e*., BG trap, CDC light traps (CDC-LT), encephalitis virus surveillance trap, and mosquito triple trap[26]. Mean number of mosquitoes captured per day (2.5±1.0) were highest for BG traps comparable to the results of our study. Comparison of different mosquito traps provides a basis to choose the effective one and also aids in optimization to improve the efficiency. Our study provides the development of a suitable mosquito trap prototype with an improvement in cost efficiency for low-income population. However, there is still scope for the optimization of our developed mosquito trap prototype. The control of carbon dioxide release rates as well as the use of attractant light for trapping could be utilized in further improvement of the prototypes for efficient mosquito trapping.

5. Conclusions

In conclusion, mosquito trap prototypes I, II, and III were successfully developed and trap efficiency was compared to commercial products. Mosquito trap prototype III provides an economic and viable solution to trap the mosquitoes and prevent bites thus enhancing protection against the vector-borne diseases such as those originated from mosquito bites, mainly for low-income population.

Conflict of interest statement

The authors declare that there is no conflict of interest.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon request.

Authors' contributions

Thapa RK contributed to conceptualization, writing original draft, reviewing and editing, visualization, validation, supervision, project administration, methodology, investigation, formal analysis, data curation, resources, and funding acquisition. Poudel SR contributed to conceptualization, reviewing and editing, visualization, validation, formal analysis, and data curation. All authors reviewed and approved the final version of the manuscript.

References

[1] Wilson AL, Courtenay O, Kelly-Hope LA, Scott TW, Takken W, Torr SJ, et al. The importance of vector control for the control and elimination of vector-borne diseases. *PLOS Negl Trop Dis* 2020; **14**(1): e0007831.

[2] Ewing DA, Cobbold CA, Purse BV, Nunn MA, White SM. Modelling the effect of temperature on the seasonal population dynamics of temperate mosquitoes. *J Theor Biol* 2016; **400**: 65-79.

[3] Ahmed T, Hyder MZ, Liaqat I, Scholz M. Climatic conditions: Conventional and nanotechnology-based methods for the control of mosquito vectors causing human health issues. *Int J Environ Res Public Health* 2019; **16**(17): 3165.

[4] World Health Organization. *World Malaria Report 2021*. [Online] Available from: https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2021. [Accessed on 3 February 2022].

[5] World Health Organization. WHO's response to dengue. [Online] Availabe from: https://cdn.who.int/media/docs/default-source/documents/emergencies/2024-appeals/dengue---who-2024-health-emergency-appeal.pdf?sfvrsn=3dd01b4c_1&download=true. [Accessed on 20 March 2025].

[6] Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG, et al. Refining the global spatial limits of dengue virus transmission by evidence-based consensus. *PLOS Negl Trop Dis* 2012; **6**(8): e1760.

[7] World Health Organization. Dengue and severe dengue. 2023. [Online] Available from: https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue. [Accessed on 6 May 2023].

[8]Ferguson NM. Challenges and opportunities in controlling mosquito-borne infections. *Nature* 2018; **559**(7715): 490-497.

[9]Lengeler C. Insecticide-treated bed nets and curtains for preventing malaria. *Cochrane Database Syst Rev* 2004; **2**: CD000363.

[10]Augustincic Polec L, Petkovic J, Welch V, Ueffing E, Ghogomu ET, Pardo JP, et al. Strategies to increase the ownership and use of insecticide-treated bednets to prevent malaria. *Cochrane Database Syst Rev* 2015: **3**: CD009186.

[11]Pluess B, Tanser FC, Lengeler C, Sharp BL. Indoor residual spraying for preventing malaria. *Cochrane Database Syst Rev* 2010; **4**: CD006657.

[12]Maia MF, Kliner M, Richardson M, Lengeler C, Moore SJ. Mosquito repellents for malaria prevention. *Cochrane Database Syst Rev* 2018; **2**(2): 011595.

[13]Hanem Fathy K, Selim AM, Abouelella GA, Abouelella NA, Murugan K, Vaz P, et al. *Commercial mosquito repellents and their safety concerns, in Malaria*. IntechOpen: London; **2019**.

[14]Joshi RK, Satyal P, Setzer WN. Himalayan aromatic medicinal plants: A review of their ethnopharmacology, volatile phytochemistry, and biological activities. *Medicines* (*Basel*) 2016; **3**(1): 6.

[15]McMeniman CJ, Corfas RA, Matthews BJ, Ritchie SA, Vosshall LB. Multimodal integration of carbon dioxide and other sensory cues drives mosquito attraction to humans. *Cell* 2014; **156**(5): 1060-1071.

[16]DeGennaro M, McBride CS, Seeholzer L, Nakagawa T, Dennis EJ, Goldman C, et al. orco mutant mosquitoes lose strong preference for humans and are not repelled by DEET. *Nature* 2013; 4**98**(7455): 487-491.

[17]Raji JI, DeGennaro M. Genetic analysis of mosquito detection of humans. *Curr Opin Insect Sci* 2017; **20**: 34-38.

[18]Cardé RT. Multi-cue integration: How mosquitoes find a host. *Curr Biol* 2015; **25**(18): R793-R797.

[19]Cribellier A, Spitzen J, Fairbairn H, van de Geer C, van Leeuwen JL, Muijres FT. Lure, retain, and catch malaria mosquitoes. How heat and humidity improve odour-baited trap performance. *Malar J* 2020; **19**(1): 357.

[20]Chaiphongpachara T, Bunyuen P, Khlaeo Chansukh K. Development of a more effective mosquito trapping box for vector control. *Sci World J* **2018**; 6241703. doi: https://doi.org/10.1155/2018/6241703.

[21]Li M, Beko G, Zannoni N, Pugliese G, Carrito M, Cera N, et al. Human metabolic emissions of carbon dioxide and methane and their implications for carbon emissions. *Sci Total Environ* 2022; **833**: 155241.

[22]McPhatter L, Gerry AC. Effect of CO_2 concentration on mosquito collection rate using odor-baited suction traps. *J Vector Ecol* 2017; **42**(1): 44-50.

[23]Yi H, Devkota BR, Yu J-S, Kim HJ. A research for an eco-friendly mosquito control by using a new mosquito trap (Mos-hole trap) in a cowshed in Yeoju of Korea. *Anim Cells Syst* 2014; **18**(4): 282-290.

[24]Zhou YH, Zhang ZW, Fu YF, Zhang GC, Yuan S. Carbon dioxide, odorants, heat and visible cues affect wild mosquito landing in open spaces. *Front Behav Neurosci* 2018; **12**: 86.

[25]Goi J, Koinari M, Muker S, Vinit R, Pomat W, Williams DT, et al. Comparison of different mosquito traps for zoonotic arbovirus vectors in Papua New Guinea. *Am J Trop Med Hyg* 2022; **106**(3): 823-827.

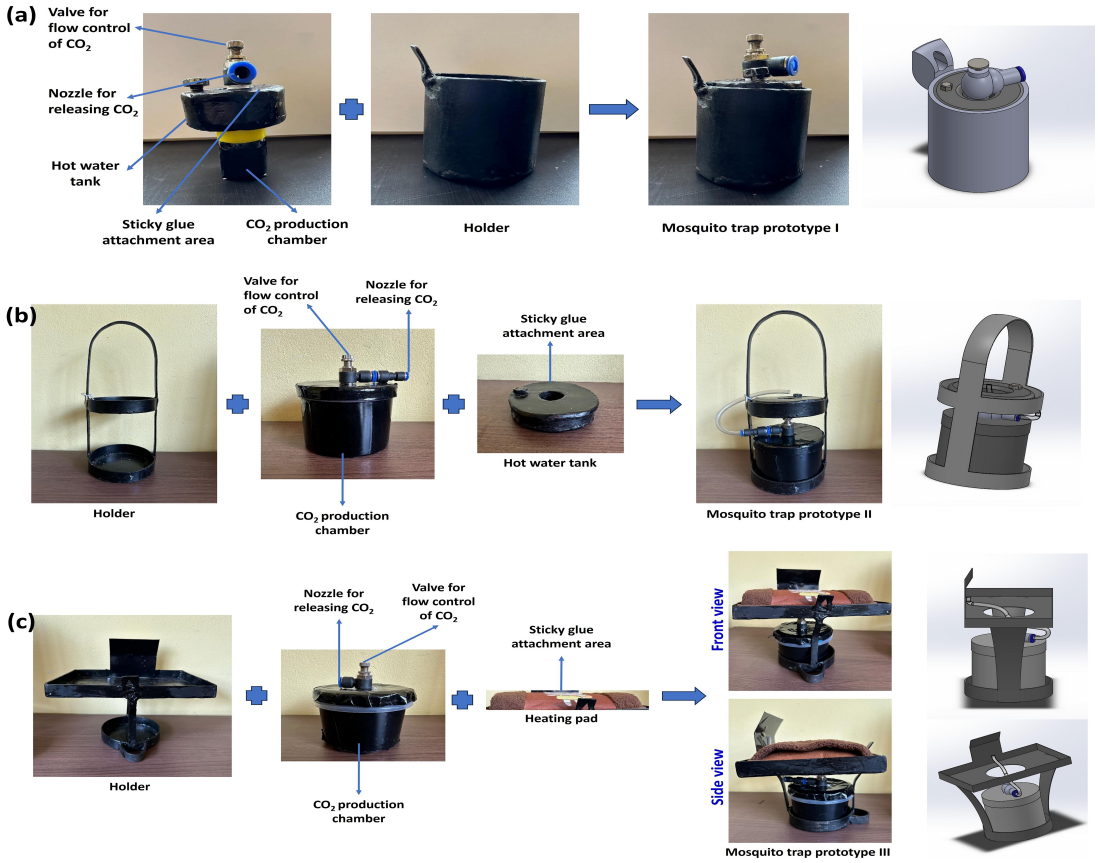
[26]Bisia M, Papadopoulos P, Filis S, Beleri S, Tegos N, Lamprou GK, et al. Field evaluation of commonly used adult mosquito traps in Greece. *Vector Borne Zoonotic Dis* 2023; **23**(3): 119-128.

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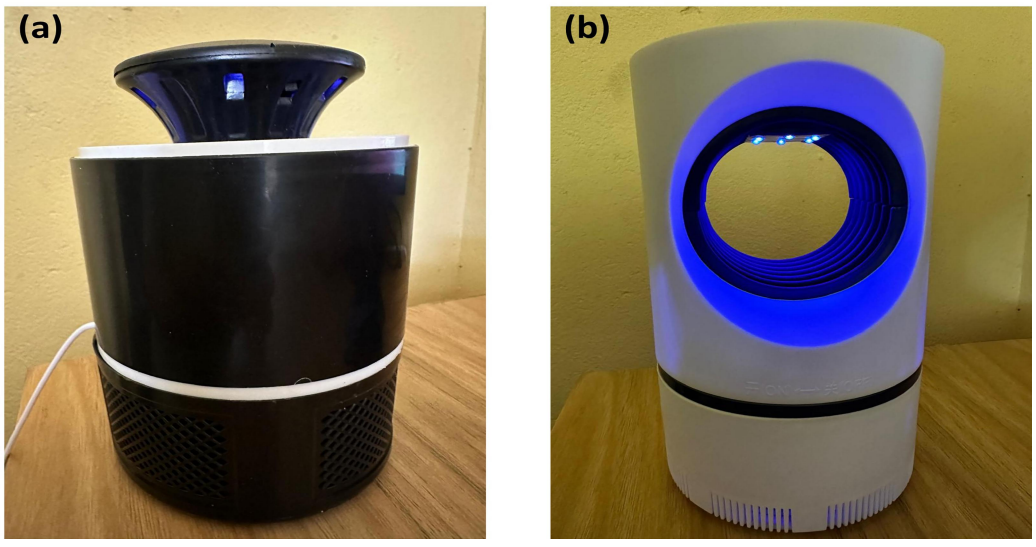
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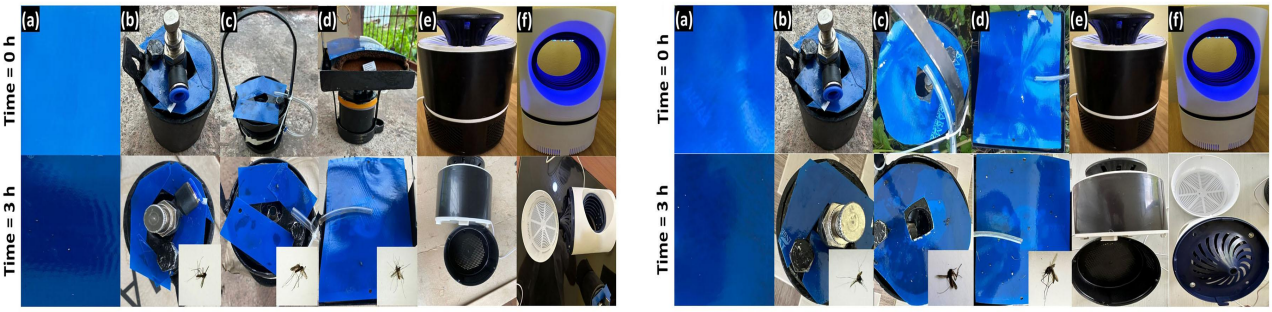
Supplementary materials



Supplementary Figure 1. Mosquito trap prototypes (a) I, (b) II, and (c) III.



Supplementary Figure 2. Commercial mosquito traps used for comparison with the developed prototypes. (a) Commercial mosquito trap I (Lightning mosquito lamp; product model: JT-Z01; Made in China) and (b) Commercial mosquito trap II (Photocatalysis suction type mosquito killer; product model: BG-360; Made in China).



Supplementary Figure 3. Representation of the mosquitoes trapped (mean capture number per trap) in (a) sticky glue only, (b) mosquito trap prototype I, (c) mosquito trap prototype II, (d) mosquito trap prototype III, (e) commercial mosquito trap I, and (f) commercial mosquito trap II at 0 h and 3 h following carbon dioxide production using (i) citric acid:sodium bicarbonate (1:2) and (iii) citric acid:sodium bicarbonate (1:1). A representative image of trapped mosquito is presented in figure insert.