Design, Manufacture, and Construction of an Inexpensive 3D-printed CO_2-baited EVS Trap

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Introduction

Of tantamount importance to the study of arbovirus prevalence in mosquitoes and mosquito abundance is the collection of mosquitoes in the field. Monitoring adult mosquito abundance accounts for a sizeable portion of the laboratory work for many districts. Adult mosquito abundance can be estimated using Encephalitis Vector Survey (EVS) traps, which use a light source and carbon dioxide (CO_2) to lure mosquitoes to the proximity of a small fan. If the mosquitoes are near enough to the fan, they can be pulled through the wind vortex into a closed net, and later, identified to species and enumerated. EVS traps purchased from commercial vendors cost approximately $120, when the cost of rechargeable batteries is included. The wide availability and low price of fused filament fabrication 3D printers allows for the manufacture of EVS traps that can cost less than purchasing traps. A 3D printer can also be programed to produce nearly any 3D object that can be accommodated on the printing platform, thereby enabling rapid prototyping and production of novel trap designs. The wide array of plastic filaments available for 3D printing offers a range of physical and mechanical properties such as durability, resilience to ultraviolet (UV) radiation, and biodegradability, that can be built into the trap. The 3D printed EVS trap that is described herein was printed using acrylonitrile styrene acrylate (ASA) filament which offers increased UV resistance and physical hardiness relative to polylactic acid (PLA) which is used in many hobbyist 3D printers. The trap was designed using 3D modeling software with the principal of modularity to simplify repairs and customizability to accommodate unusually shaped batteries. Using 3D printers enables the production of fully customized and novel mosquito traps without having to spend exorbitant funds for purchase.

Methods

Two types of plastic filament were used for our trap development: ASA, which offers UV resistance as well as durability, and PLA which is both inexpensive and compostable. A consideration to the selection of a primary printing material is based on the printing machine to be used. Two 3D printers were used to develop and print the EVS trap: (1) a single-nozzle, PLA-only Flashforge Finder printer (Flashforge USA, City of Industry, CA) and the Ultimaker 3 Extended with dual nozzles and a heated bed (Ultimaker, Utrecht, the Netherlands) for printing a wide range of thermoplastics. The high glass transition temperature of ASA requires the use of a 3D printer with a heated bed to prevent warping of the object being printed. Three different 3D-modeling software applications were utilized for this project: Tinkercad (Autodesk Inc., San Rafael, CA), Blender (Stichting Blender Foundation, Amsterdam, the Netherlands), and AutoCAD (Autodesk Inc., San Rafael, CA). The free-to-use software Tinkercad is user-friendly, but it cannot make intricate, mechanically precise models. Blender, while free, requires greater effort to learn and is used more frequently as artistic modeling software rather than an engineering tool. AutoCAD was utilized primarily to construct 3D models of the EVS trap parts (Fig 1A.). Thingiverse, available at thingiverse.com, is a repository of 3D models. It is a free service, but it requires one to upload the designs to the website. Once all seven trap parts had been designed and printed, the additional parts were purchased and assembled to produce the completed 3D printed trap (Fig. 1B). The required additional parts, available from a variety of vendors, include: fan motor (model RF500TB-14415; Solarbiotics, Calgary, Canada), 4 blade 74 mm diameter fan blade (BioQuip Products, Rancho Dominguez, CA), ultra bright white 12V light-emitting diode, a universal serial bus (USB) cable to deliver the necessary energy from the battery, 20000 mAh lithium-ion polymer (LiPo) double USB battery (model 26111700; AiBOCN, Wilmington, DE), a cable from which the trap could be hung, nuts, screws, and 140 mm threaded rods to provide reinforcement and mounting. The 3D printed trap was compared to a conventional Heavy Duty EVS CO_2 Mosquito Trap (BioQuip Products, Rancho Dominguez, CA) to determine the suction force it produced using a Kestrel 5500 Weather Meter (Kestrel Instruments, Boot-wyn, PA). The quantity of CO_2 released from the EVS traps was assessed using a CO_2 monitor (pSense High Accuracy ($\pm$ 30ppm) Portable CO_2 Meter,Senseair AB, Delsbo, Sweden). The mean and standard error of the mean (SEM) of two measurements at each distance was calculated and graphed using Prism Software (version 8.4.2; GraphPad Software, San Diego, CA)

Figure 1.—(A) 3D model of the EVS trap produced using AutoCAD software. (B) Assembled 3D printed EVS trap.

Results

All seven trap parts were printed using the Ultimaker 3D printer in 14 h. Once the parts were printed and other materials collected, the assembly of a complete 3D trap took 15 min. The total cost of a completed 3D trap was less than $54. The first test performed on the trap was an assessment of the fan power compared to the original, purchased EVS trap. Using a wind meter, the original EVS trap had an inward wind speed of 0.85 m/s whereas the 3D-printed trap was 1.4 m/s. The wind speed leaving the trap was 2.2 m/s for the original EVS trap and 3.1 m/s for the 3D-printed EVS trap. The second test was to assess the dispersal of CO_2 from the center of the traps. CO_2 concentration was measured 60 min after dry ice was placed into a standard EVS trap bucked that was suspended

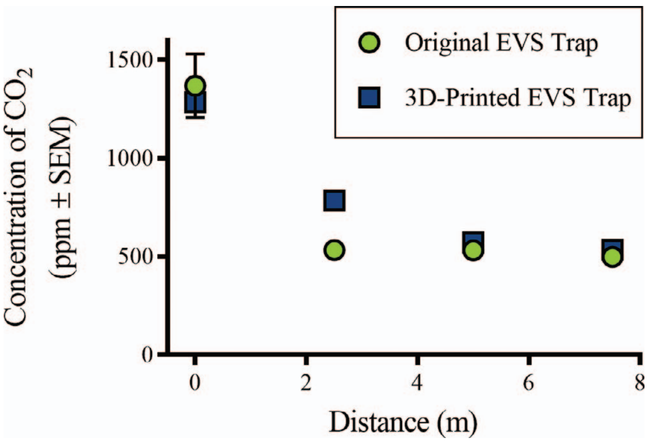

Figure 2.—The dispersal distance of CO_2 from the original EVS trap and the 3D-printed EVS trap.

above the traps at distances of 0 m, 2.5 m, 5 m, and 7.5 m. The results suggest that the original and 3D-printed traps disperse CO_2 with similar efficiency (Figure 2).

Discussion

A complete comparison of the strength of the two thermoplastics we used to 3D print EVS traps will require more study. However, during our brief use of the two traps in the field, PLA seemed to perform as well as ASA. The strength of PLA may be adequate in the short term but become weaker upon repeated, long term use. Because the cost for a printer that utilizes only PLA is much less than one that uses a broader range of thermoplastics, the PLA-only 3D printer is an appealing option to consider for those wishing to minimize cost. In the design of the 3D model, AutoCAD was preferred to the other modeling software that was evaluated. The amount of constructive control of the sculpted object as well as the intuitive interface for the formation of mechanical objects made AutoCAD the ideal application for trap design. Price was the driving factor for selecting the USB LiPo battery. The ubiquity of rechargeable USB LiPo batteries has driven down cost while increasing the power capacity. Moreover, LiPo batteries maintain their capacity for more charge-discharge cycles than the typical nickel-cadmium rechargeable batteries that are often used for the original EVS traps. In summary, we demonstrated that design, manufacture, and construction of an EVS trap can all occur on-site at a low cost using a 3D printer.

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