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A 3D printed Malaise trap head

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Abstract. We present a design for a 3D printed Malaise trap head using polylactic acid filament. The head is tested under field conditions, the polylactic acid material tested with common killing and preservation chemicals and with intense UV light. The head works successfully in the field, and the material is suitable for use with propylene glycol, dichlorvos, or EtOH solutions, but breaks down when ammonium carbonate, sodium cyanide, or ethyl acetate are used. We did not see any impact when the material was exposed to UV. Based on our success, we encourage entomologists to explore the potential for making custom 3D components for sampling insects and other field and laboratory applications. All the trap head design files are available online, free for non-commercial use.

Key Words. PLA, custom trap components, 3D printing.

INTRODUCTION

Entomologists commonly devise and build special purpose traps and sampling devices. Typically these are crafted from off the shelf parts because they are readily available and inexpensive. Even commercially produced traps are often built using hardware components that are repurposed from other applications. Although these traps and trap components are often cleverly designed and usually sufficiently effective for their purpose, a component that is designed specifically for the task at hand, rather than adopted from a plumbing application, for example, would be preferable. Making custom parts has been out of the reach of most entomologists as a result of the relatively high costs, the need for specialized tools and the skills needed to manipulate materials; i.e., most of us don't have ready access to a machine shop.

The advent of desktop 3D printing can significantly change these restrictions to designing entomological equipment. Fundamentally, 3D printing is the process of making three dimensional solid objects from a digital design file. A typical desktop approach to synthesizing an object is known as Fused Deposition Modeling (FDM), an additive process used where the printer builds up successive layers of heated material until the entire object is created. Each printed layer is a thin, horizontal cross-section of the object. With this method, anyone can design and print a trap component that exactly meets required size and shape specifications for a specific application. As is typical of electronic devices, the price for a 3D printer has dropped as the technology becomes mainstream. However, if the purchase of a 3D printer and learning to use the design software is beyond one's means or interests, there is a growing community of 3D printing services and model sharing resources available online. Entomologists have not yet fully embraced the possibilities of printing, sharing and modifying custom traps and sampling device components, but we predict that this will be very important in the future. What entomologists will make is only limited by their imaginations.

Our motivation to design a Malaise trap head stems from difficulties experienced with currently available models. Standard wet/dry heads are composed of a plastic jar, PVC connector, and small funnel. These are all glued together and sealed. Although an innovative design, there are some unavoidable problems: (1) there are three different kinds of plastics and a sealant involved, and each of these has its own specific rate and amount of expansion and contraction as temperatures change; (2) each of the materials has unique adhesive properties and reacts with sealants differently; (3) the components are not designed to work as a unit and so fit-tolerances are not standardized; and (4) the seal between the assembled components lies below the level of the fluid when using the wet head. These four features of the commercial trap heads result in frequent failure of the seal and loss of fluid. When failures occur the head needs to be either replaced or resealed. Failure in a field situation can result in a lost collecting opportunity or compromised experimental replicates. In contrast, a 3D printed head uses a single material, is printed to an exact fit, and has no seal line, thus avoiding all of these issues. If printed correctly, an undamaged printed head will never leak.

A large selection of material is now available for 3D printing. We chose to use polylactic acid (PLA) filament, a thermoplastic polyester, because it is readily available, inexpensive and ultimately biodegradable. It also can be printed at the size we required and is sufficiently strong, lightweight, and translucent. Because the trap head will be exposed to various chemicals, UV light and a range of temperatures in the field, the biodegradability of the material raised concerns that the material might break down too quickly for routine use. PLA is considered compostable, but will only quickly degrade when subject to industrial biodegradation processes that include exposure to temperatures of at least 55–70°C (Lunt 1998). PLA placed in a common backyard compost pile would not be expected to break down for many decades. Some chemicals and solutions used in entomology are very aggressive and solvent in nature, and it was unknown how they might react with and potentially break down PLA. We present tests of eight of the most common insect killing and preserving agents herein.

Materials and Methods

To create the 3D model used for our test, we developed a rough sketch into a 3D model using Maya software (Autodesk 2015), a popular computer graphics program. The software allowed for precision shaping and sizing adjustments and exported software-agnostic .stl files to a Makerbot Replicator 2 (MR2) desktop 3D printer. Using PLA material and the MR2's "medium" resolution setting of a 0.2mm layer thickness, we attempted to make a design that would print reliably and with minimal waste and cleanup.

One limitation of FDM printing is that 3D designs with significant overhangs (unsupported surfaces angling from the vertical axis in excess of roughly 45 degrees) require the use of disposable support structures on which the filament layers composing that overhang can be deposited. If these supports were not present, the filament layers would be deposited into open air, and would droop below their intended height. FDM supports, which can be designed by hand or inserted automatically by the MR2, allow for printing of overhangs as far as 90 degrees (a horizontal line) anywhere in the print area space. However, their use frequently requires time-consuming clean-up effort involving manual removal, cutting with a utility knife and sanding, which significantly increases the complexity of the print job and amount of material needed, which in turn increases waste and the likelihood of print job failure.

To keep the design as reliable and reproducible as possible on the printing end, we modified our design to include an interlocking body and lid that featured no significant overhangs and, therefore, avoided the need for temporary FDM supports. Through several iterations, we arrived at a 3D model for a trap head that satisfied both needs for 3D printing ease and speed as well as field durability and fit.

To test the suitability of the PLA material for use with chemicals or solutions commonly used in entomological work as killing and preservative agents, we cut samples of the printed material into approximately 3×5-mm pieces. We placed samples in 20-ml, poly seal scintillation vials with eight different treatments (Table 1). One sample was placed in an empty vial to act as a control. Vials were placed outside in full sun in Concord, CA from 15 August to 15 November 2015. Samples were checked periodically to ensure fluids were not evaporating. At the end of the test period samples were removed from the vials and inspected under the microscope. We recorded if there was (1) any indication of degradation, softening, breakdown, or increased brittleness, and (2) color changes or other indication of a reaction between the solutions or due to UV exposure.

To further test for resistance to UV exposure we placed three pieces of the printed material on a UV table that emits 312 nm UV for 30 minutes. At the 30-minute point, the material was very hot and the test was terminated before the samples began melting.

To test the efficacy of the trap head in the field, we set up two Malaise traps during routine monthly sampling in Mt. Diablo State Park, California, using 95% ethanol (Fig. 1). These traps are part of an ongoing study, and the heads replaced leaking commercial heads previously used. No direct, quantitative comparison was made between traps with the two styles of trap head. The test is, therefore, qualitative regarding insect capture and a subjective assessment of performance. Traps with the printed heads were used at various points from August 2015 to January 2016, run over the course of three to four days at a time.

Results

As designed, the general form of the trap head (Fig. 2) is similar to the dry-use only, BioQuip 2875H standard collecting head but can be used with fluids or dry and has

Table 1. Summary of results of exposure of PLA to common killing and preservation chemicals.

Treatment	Outcomes
No solution control	No change
100% Propylene glycol	No change
Dichlorvos [Vapona strip]	No change
Water	No change in structure, became more opaque
70% Ethanol	No change in structure, became more opaque
95% Ethanol	No change in structure, became more opaque
Ammonium carbonate	No immediate reaction, material became very soft and began breaking down
Sodium cyanide	No immediate reaction, material became very soft and began breaking down
Ethyl acetate	Immediate reaction, softening and ultimately almost entirely broken down

Figure 1. Trap with 3D printed trap head deployed at the Mt. Diablo site.

been optimized for strength, compactness and volume to suit our implementation. The weight of the printed head is approximately 227 g (0.5 lb), about 5 g lighter than the BioQuip 2875WDH wet/dry head. The full design files are available free and for non-commercial use only at http://www.thingiverse.com/thing:1284494.

Exposure to various preservatives and killing agents gave varied results. The control, propylene glycol, and dichlorvos showed no perceptible change (Table 1). Water and ethanol solutions changed the color of the PLA samples slightly, becoming paler and more opaque, but there was no evidence of any breakdown, softening or increased brittleness. Ammonium carbonate, sodium cyanide and ethyl acetate all caused obvious reactions, including notable softening and extensive breakdown. We found no indication that the material was significantly altered by UV exposure. The no-solution control and UV table exposed pieces showed no changes. There was no indication that UV and general weather conditions alter the integrity of the head during field use.

In the field, the trap heads performed well. The insect take appears as large as or larger than the take using commercial trap head. Ethanol evaporation rate was relatively low. Filling the unit with fluid and sample transfer were easily accomplished. The trap heads appear robust enough to withstand typical field use and being packed and transported with no special packaging or handling.

Discussion

This trap head design works well under field conditions and is suitable for use with some but not all killing and preserving agents. As PLA is resistant to ethanol and

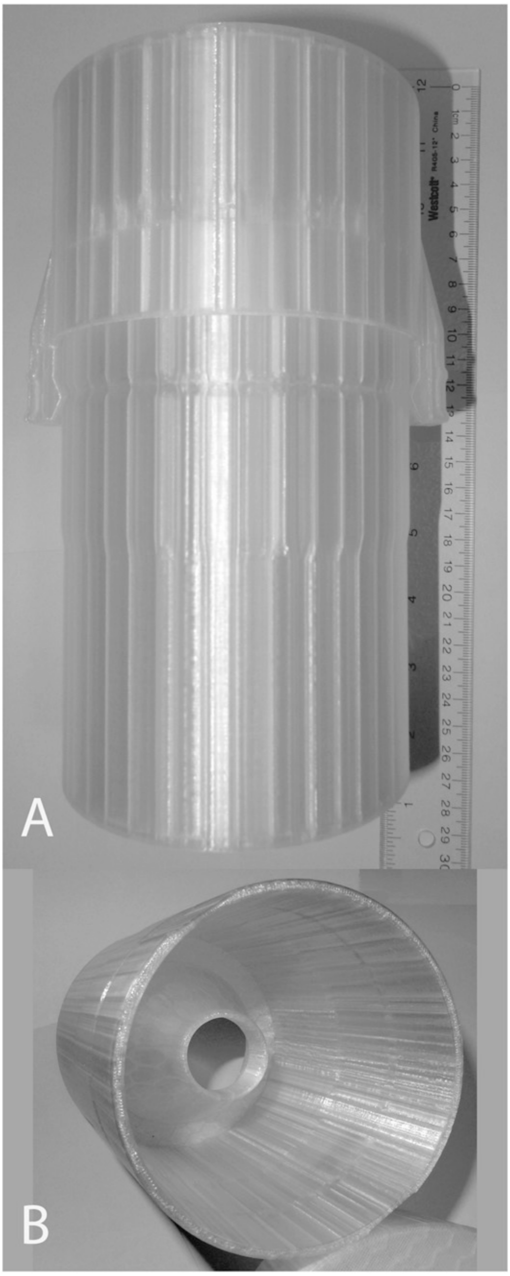

Figure 2. Trap head. A. Lateral view with lid on and B. view inside from the top showing the funnel. The inner diameter of the funnel hole fits a standard #6 rubber stopper.

propylene glycol, two of the most common solutions used in traps, we think this material is a good choice for most applications. PLA is also ultimately biodegradable and is derived from renewable resources, such as cornstarch, sugar cane, tapioca roots or potato starch. This makes PLA a more environmentally sustainable solution. However, if one needs to use cyanide or ethyl acetate, alternative materials should be used for the head; e.g., nylons or polymethylpentene.

PLA is relatively UV stable but is subject to photodegradation (Yasunda et al. 2010). Because there can be differences in the manufacturing of PLA stock filament, printing may incorporate impurities that can alter the UV resistance (Araújo et al. 2013), and durability is impacted by the print design, it is difficult to generalized results for exposure in our specific application. Anecdotally, but consistent with our results, we found many reports online of instances of PLA objects printed for outdoor applications that had been exposed constantly for a year or more without noticeable degradation.

PLA costs approximately $45 (U.S. dollars) for a two-pound spool. Given an allowance for some waste and printing error, three heads can easily be printed from a single spool. Using our design http://www.thingiverse.com/thing:1284494 the material costs are about $12–15 per head to print the head on a personal 3D printer. Maya software is relatively expensive and has functionality that greatly exceeds what is needed for printing the Malaise trap head. There are many alternative software applications that are much less expensive that can be readily found by searching for 3D modeling software online. Many people do not yet have personal 3D printers, which would be a significant investment. However, there are many 3D printing services now available online. Cost estimates provided by several 3D print hubs (e.g., https://www.3dhubs.com/) and companies providing printing services, including the cost of material, ranged from $47–195 for a single head (searches done on 6 March 2016). However, there was a steep volume discount, such that ordering four heads reduced the lowest estimate to just over $23 per head. The comparable collecting head from BioQuip (#2875WDH) currently sells for $48.70, making a 3D printed head a cost-effective alternative with many advantages.

This trap head design is just one example of the potential of 3D printing for entomological applications. We expect that many readers are now thinking of how they may modify or improve the design presented here to suit their own applications.

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