Single Use PLA Biodegradable Water Bottle

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Abstract

- Consumption of single use water bottles has significantly increased which negatively affected the environment
- PLA (Polylactide) plastic is an alternative to conventional plastics because of biodegradability
- Grand Challenge: Minimize plastic pollution
- Solution: Replace conventional plastics with biodegradable PLA plastic
- Two PLA bottles, Bottle A and Bottle B, were designed using Tinkercad software and 3D printed for experimentation
- The bottles durability was tested by observing water leakage, exposing them to high temperature water and high temperature air
- Durability was compared by measuring the amount of volume lost after each experiment

Introduction

- In 2017, landfills received 26.8 million tons of plastic. This was 19.2 percent of all municipal solid waste landfilled (Waster, 2021)
- In 2017 - 35,370 tons of plastic was generated, and 26,820 tons of plastic entered the landfill --- only 2,960 tons were recycled (Duong, 2020)
- Study found the average American can save $1,236/year if using a reusable water bottle instead of buying plastic (Davis et al. 2015)
- Rationale Goal: curb plastic consumption, by eliminating one of the greatest sources of plastic usage by offering a compostable alternative
- 480 billion plastic water bottles are sold yearly --- only 50% of all bottles are recycled --- only 7% are turned into new bottles (Figure 1)
- It takes 450 years for a commercial plastic water bottle to biodegrade (Figure 2)

Figure 1: Statistics on the Plastic Water Bottle (Trowsdale, 2017)

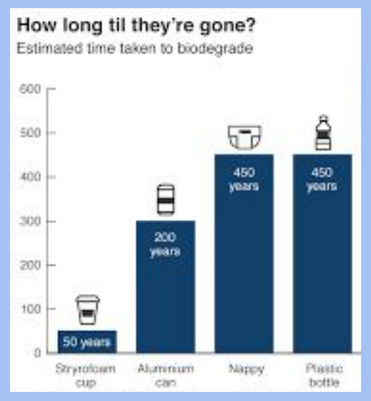

Figure 2: The biodegradability Timeline of Different Plastic Sources (Trowsdale, 2017)

- Aluminum was the first proposed material, however, multiple companies have already produced single use aluminum water bottles

Solution to Plastic Pollution

- Knowledge gap: Can PLA products perform optimally after single use
- Create a biodegradable single use water bottle and test its durability
- If the water bottle can function properly without being affected by biodegradability, then it could be an alternative to commercial plastic bottles

PLA Plastic Comparison

- Goal: Compare plastic materials for the prototype water bottle
- Durability of the materials was compared by observing water leakage, water absorption and deformities from high temperatures
- Results: 7oz Disposable Cup-Biodegradable was the most durable because there was no water leakage or absorption, minimal deformities, and was the most cost effective
- These results prompted a goal to build a water bottle from the same or similar material to the test cup

PLA Bottle Comparison

- Goal: Design and create 3D prototypes of the biodegradable bottle
- Materials and Methods: Tinkercad was used to design and print bottle prototypes using PLA material. The designs of the bottles were sleek, efficient, and simple (Figure 4, 5). Bottle caps were not included

Bottle A

Figure 4: 3D and printed model of Bottle A

Bottle B

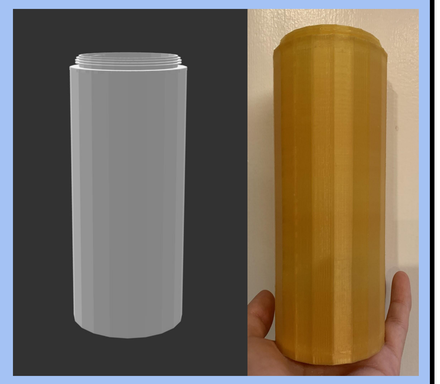

Figure 5: 3D and printed model of Bottle B

Procedure

Before each experiment, the bottles were filled with water and volume was recorded.

A: Assessing Water Leakage

- Each bottle was filled with water
- The amount of water that leaked out was measured over the duration of 10 minutes

B: Test Durability of Bottle in Heated Water (Boiling Water):

- A metal pot with water was heated until boiled
- The pot was taken off of the heat and the bottle was placed into the boiling water
- The bottle was left in the water for 10 minutes, then removed to cool on flat surface in a vertical, upright position
- The bottles were filled with room temperature water and the amount held was measured with a 500ml glass measuring cup and recorded along with structural changes

C: Test Durability in High Temperature Air (Oven):

- An oven was heated to 107°C
- The bottles were placed onto a baking sheet covered with parchment paper and were placed into the oven for seven minutes
- If the bottles were burned, they were removed
- If there were no burns, they remained in the oven for the total seven minutes
- The bottles were removed and cooled on a flat surface in a vertical, upright position
- The bottles were filled with room temperature water and the amount held was measured with a 500 ml glass measuring cup and was recorded along with structural changes

The experiments were not replicated.

Results

Table 1: Model Testing Data

	Volume Before Testing (ml)	Volume Lost After Water Leakage Test (ml)	Volume Lost After Heated Water Test (ml)	Volume Lost After High Temperature Air Test (ml)
Bottle A	394.22	157.63	78.67	110.31
Bottle B	473.18	0	118.29	118.29

Figure 6: Images of Bottle A and B after the water leakage experiment

Figure 7: Images of Bottle A and B after the heated water experiment

Figure 8: Images of Bottle A and B after the high temperature experiment

Discussion

- Part A: Bottle A lost 40% volume while Bottle B lost 0% (Table 1) and had no visible leakages (Figure 6)
- Part B: Bottle A lost 20% volume while Bottle B lost 25% (Table 1). Both bottles had similar deformations (Figure 7)
- Part C: Bottle A lost 28% volume while Bottle B lost 25% (Table 1). Both bottles had similar deformations (Figure 8)
- Bottle A lost less volume during the heated water test and Bottle B lost less volume during the water leakage and high temperature air test

Conclusion and Environmental Impact

- Bottle B performed better in more categories than Bottle A, therefore, Bottle B is our choice as the project moves forward
- Future goals include making modifications to Bottle B and distributing the upgraded version to Chapman students to spread awareness about importance of plastic pollution and the environment
- Plastic bottle manufacturers should consider PLA as an alternate material to conventional plastics

Minimizing Plastic Pollution

- When conventional plastics are in the environment, they leach chemicals and toxins into soil and water (Halden 2010)
- PLA breaks down into its constituent parts within three months and does not leach chemical into the environment (Hottle et al. 2016)
- PLA corn-plastic is partially plant-based-it can be recycled or composted (Hottle et al. 2016)

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