The Effect of Dulbecco's 'Eagle' Medium on the Mass and Tribological Characteristics of PLA Samples: A Preliminary Study

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Abstract: This preliminary study investigates the influence of Dulbecco's Eagle medium on the mass stability and tribological performance of polylactic acid (PLA) samples produced by FDM 3D printing. Black PLA filament was printed on a Bambu Lab X1 Carbon printer with 15% and 20% infill densities. The samples were immersed in Dulbecco's Eagle medium for 7 days at 37 ± 1 °C, followed by 24 h of drying, and their mass was measured using a Kern AET-200 digital analytical balance. Mass results revealed a significant loss for the 15% infill samples (5.07%), while the 20% infill samples showed minimal change (0.29%). Tribological tests using a CSM nanotribometer indicated a higher coefficient of friction and deeper penetration depth for 15% infill specimens compared to 20% infill ones, confirming the role of structural density in degradation resistance. Future work will address infill variations up to 100% and longer immersion periods to evaluate long-term stability.

Keywords: PLA, FDM 3D printing, mass loss, tribology, infill density

1. Introduction

Polylactic acid (PLA) is a biodegradable and bio-based thermoplastic polymer that has attracted increasing interest due to its environmental sustainability, biocompatibility, and versatility in applications ranging from biomedical devices to additive manufacturing and packaging [1, 2]. Despite these advantages, PLA exhibits inherent drawbacks such as low thermal stability, brittleness, and relatively poor mechanical and tribological performance compared to petroleum-based polymers [3]. These limitations have driven research efforts to enhance the structural, mechanical, and surface properties of PLA.

In addition to tribological characteristics - such as friction, wear resistance, and surface durability - the mass stability of PLA is a critical parameter when the material is exposed to different environments. Changes in mass can occur due to hydrolytic degradation, water uptake, or biochemical interactions, all of which directly affect mechanical integrity and surface behavior. Mass variations are therefore a valuable indicator of degradation kinetics and long-term material performance.

Dulbecco's Modified Eagle Medium (DMEM), widely used in cell culture applications, has been reported to accelerate polymer degradation by providing an aqueous, ion-rich environment that promotes hydrolysis and alters surface chemistry [4]. Previous studies have demonstrated that biodegradable polymers immersed in DMEM or similar culture media undergo measurable mass loss over time, accompanied by changes in crystallinity, morphology, and tribological properties [5,6]. However, the specific effect of Dulbecco's "Eagle" medium on the mass and tribological characteristics of PLA samples has not yet been systematically studied.

This preliminary study aims to explore the influence of Dulbecco's "Eagle" medium on the mass stability and tribological performance of PLA samples. By quantifying mass changes and evaluating friction and wear behavior, the work seeks to establish a foundation for further studies focused on tailoring PLA for biomedical and engineering applications where exposure to biochemical environments is unavoidable.

2. Methodology

PLA filament (1.75 mm diameter; black PLA) was used for FDM 3D printing of the samples on a Bambu Lab X1 Carbon printer, using Bambu Lab Studio slicer software. The 3D printing parameters were as follows: nozzle temperature 200 °C, platform temperature 60 °C, printing speed 60 mm/s, layer height 0.1 mm, and wall thickness (shell) 0.4 mm. Two sets of samples were fabricated with 15% and 20% infill density, as shown in Figure 1 (left and center), while the mass of the samples was measured using a digital analytical balance (Kern AET-200), as shown in Figure 1 (right). The dimensions of the printed samples were 10 mm × 10 mm × 10 mm.

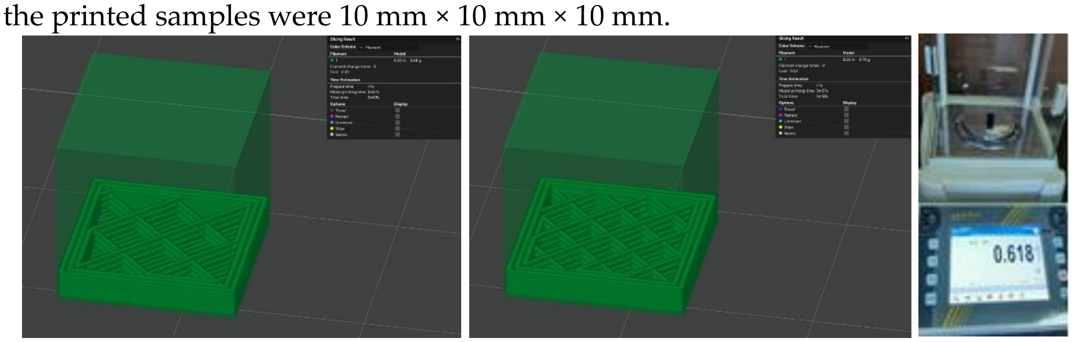

Figure 1. Schematics of PLA 3D printing with 15% infill (left) and 20% infill (center), and the digital analytical balance used for mass measurement (right)

The printed samples were immersed in Dulbecco's Eagle medium and kept for 7 days at a temperature of 37 ± 1 °C to simulate physiological conditions. After the immersion period, the samples were removed from the medium and left to dry at room temperature for 24 hours in order to eliminate excess surface liquid. Only then was the mass of the samples measured with a digital analytical balance (Kern AET-200). This procedure ensured that the recorded values reflected potential mass loss due to PLA degradation rather than the presence of residual medium.

Tribological tests were carried out using a CSM nanotribometer equipped with a rotational ball-on-flat module. A silicon nitride (Si_3N_4) ball with a diameter of 1.5 mm served as the counterbody in contact with the flat 3D-printed PLA samples. The tests were performed under dry contact conditions, with a total of 1800 laps at a rotation radius of 1.5 mm and a linear sliding speed of 10 mm/s, while applying a normal load of 5 mN.

3. Results and Discussion

The nominal mass of the samples, estimated by the slicer, was 0.680 g for the 15% infill and 0.700 g for the 20% infill configuration. Experimental measurements prior to immersion gave slightly lower values of 0.651 g and 0.695 g, reflecting minor discrepancies between slicer predictions and actual printed specimens.

After 7 days of immersion in Dulbecco's Eagle medium, followed by 24 h of drying at room temperature, the samples showed different mass retention behavior. The 15% infill samples decreased from 0.651 g to 0.618 g, corresponding to a relative loss of 5.07%. In contrast, the 20% infill samples remained almost unchanged, decreasing from 0.695 g to 0.693 g, a relative change of only 0.29%.

These results indicate that lower-infill PLA is more susceptible to degradation when exposed to Dulbecco's Eagle medium, likely due to its larger internal surface area and open structure, which facilitates fluid penetration. Conversely, the denser 20% infill structure showed greater resistance to mass loss, confirming better stability under simulated physiological conditions.

Tribological tests performed after 7 days of immersion in Dulbecco's Eagle medium revealed clear differences between the 15% and 20% infill samples. The coefficient of friction (COF) was 1.066 for 15% infill compared to 0.916 for 20% infill, showing that denser samples provide better tribological performance with reduced friction under identical conditions.

Penetration depth also differed significantly between the groups. The 15% infill samples reached 64,130 nm, whereas the 20% infill samples showed a much lower value of 48,344 nm. The higher penetration depth in the 15% infill group indicates greater material removal and weaker resistance to surface deformation, which is consistent with their lower mass stability and higher susceptibility to hydrolytic degradation.

Overall, these findings confirm a strong link between infill density, mass stability, and tribological behavior. The 20% infill specimens not only retained their mass more effectively but also exhibited lower friction and shallower penetration depth, demonstrating superior wear resistance under simulated physiological conditions.

4. Conclusions

This preliminary study examined the effect of Dulbecco's Eagle medium on the mass stability and tribological characteristics of PLA samples produced by FDM 3D printing. The results demonstrated that samples with lower infill (15%) exhibited a significantly higher mass loss and poorer tribological performance compared to samples with higher infill (20%). Specifically, the 15% infill specimens showed greater susceptibility to hydrolytic degradation, higher coefficients of friction, and deeper penetration depths under tribological testing. In contrast, the 20% infill samples displayed superior mass retention and enhanced resistance to wear, confirming the influence of structural density on the durability of PLA in simulated physiological conditions.

Overall, these findings highlight the importance of infill density as a design parameter that directly impacts both degradation resistance and tribological behavior of PLA. As a direction for future research, it will be essential to investigate a broader range of infill densities up to 100%, as well as to extend the immersion period in Dulbecco's Eagle medium, in order to gain deeper insight into the long-term performance and degradation mechanisms of PLA under biochemical exposure.

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