DESIGN AND FABRICATION OF AN INTESTINAL PHANTOM TO MIMIC INTESTINAL MOTILITY

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Introduction

Modelling gut motility is important for the study of gut dysfunctions, which are known to affect nutrient absorption [1]. However current systems are not able to provide a human-relevant model at the macroscale [2]. The aim of this work is thus to engineer a physical twin replicating gut architecture, mechanical features, and dynamics as well as the rheological properties of the luminal content.

Methods

Polydimethylsiloxane (PDMS) samples were prepared at different monomer - crosslinking agent ratios: 4:1, 5:1, 6:1 and 7:1. Tensile tests were performed at a strain rate of 6 mm/s using a universal testing machine (Zwick-Roell, Z005 ProLine). A 60% maximum deformation was selected corresponding to the limit beyond which the muscle, at a physiological level, remains in the elastic regime [3]. Buffer solutions were obtained by dissolving 0.681% w/v potassium dihydrogen phosphate and 0.022, 0.1164, and 0.187% w/v sodium hydroxide in distilled water, obtaining solutions at pH 6, 7 and 8. pH values were assessed with a pH meter (Hanna, Edge series). Pectin from 0.5 to 5% w/v was then dissolved in the buffer solutions. Viscosity measurements were performed using a Brookfield DV-II+PRO Viscosimeter. The phantom was finally designed using Computer Aided Design (CAD) software (Fusion 360), reproducing the anatomical shape of the bowel.

Results

Figure 1 shows the technical drawings of the duodenum and the resulting PDMS prototype.

Figure 1: Comparison between physiological duodenum and a) anatomical technical drawings. b) PDMS prototype.

As expected, Figure 2 shows that PDMS apparent elastic moduli decrease with increasing monomer - crosslinking agent ratio and that pectin viscosity increases as a function of concentration and decreases as the pH increases.

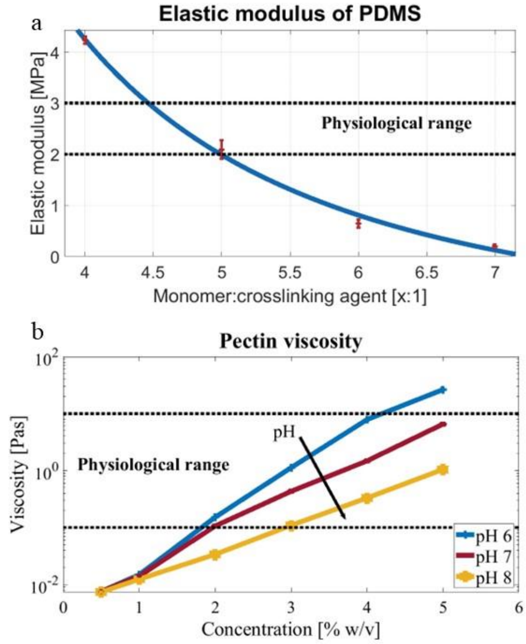

Figure 2: a) Elastic modulus of PDMS at different ratios and b) pectin viscosity in buffer solutions with different pH, plotted in logarithmic scale with respect to pectin concentration.

Discussion

The 5:1 ratio resulted closer to the desired value of 2.09 ± 0.17 MPa (2-3 MPa [3-4]) and was thus selected for phantom fabrication**.** Moreover, pectin viscosities resulted within the desired physiological range (1-10 s^{-1} [5]) at the different pH values corresponding to physiological pH variations in the gut [6]. Replicating luminal content rheology is indeed fundamental to assess its propulsion within the bowel.

Conclusions

In this study, materials able to replicate the mechanical and rheological features of the gut and luminal content were defined, enabling the prototyping of a physical twin. Future studies are ongoing to increase the PDMS surface's hydrophilic properties, enabling the coupling with an intestinal mucosal layer. In the future, this model can be used to investigate the efficacy of treatments to restore gut motility.

References

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