Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

SMART CAPSULES FOR THE TARGETED SAMPLING OF MICROBIOTA WITHIN THE GASTROINTESTINAL TRACT

Hanna Hamoud-Michel[1,2], Sydney Wheatley[1,2], Irah King[3,4], Corinne Maurice[3], Ali Ahmadi[1,2*]
[1]Department of Mechanical Engineering, École de technologie supérieure (ÉTS), Montreal, Canada
[2]University of Montreal Hospital Research Center (CRCHUM), Montreal, Canada
[3]Department of Microbiology and Immunology, McGill University, Montreal, Canada
[4]McGill University Health Centre Research Institute, Montreal, Canada
*ali.ahmadi@etsmtl.ca

ABSTRACT

The gut microbiota, composed of trillions of microorganisms residing in the gastrointestinal (GI) tract, regulates key functions of the human body, including digestion, metabolism and immune function. Current research has demonstrated that changes in the microbial composition of the gut are linked to diseases such as digestive disorders and cancer. Despite this, the exact causes of bacterial dysbiosis and its relationship with human health remain unclear. Therefore, gaining a better understanding of this link is essential for the prevention and treatment of these diseases.

To analyze the gut microbiota, samples must first be acquired. However, current sampling methods are inefficient. Indeed, stool samples are imprecise, while biopsies are invasive and alter the gut composition. Smart ingestible capsules have been developed to address these limitations, but remain inefficient. These capsules often rely on electronics, which pose safety risks, or magnetic actuation, which is imprecise. They are also often limited to one area of the tract, requiring multiple ingestions to achieve a comprehensive analysis of the entire tract.

Hence, we have microfabricated a passive capsule for targeted sampling of different areas of the GI tract. The ingestible capsule was designed on Solidworks (Dassault Systems) and fabricated using 3D printing techniques (Form3B, Formlabs). Degradable polymer films serve as a targeting mechanism by leveraging the varying pH levels throughout the gastrointestinal tract. To achieve this, soluble alginate films are attached to the capsule opening using silicone rubber (dimethyl hydrogenpolydimethylsiloxane). The alginate is then dip-coated in Eudragit L100 (6.2% w/w Eudragit and 0.6% w/w triethyl citrate), a pH-sensitive polymer that degrades in the small intestine. Additionally, a polyacrylamide hydrogel (45% w/v acrylamide, 1.5% w/v N,N′ -methylenebisacrylamide and 1% w/v ammonium persulfate) swelling mechanism is employed to seal the device after sampling, preventing further contamination during its passage through the tract. Hydrogel swelling ratio and compressive strength were evaluated to demonstrate sample preservation. Sample contamination was assessed through the leakage of dye and fluorescent particles (1µm diameter). Finally, the capsule can be recovered and its contents analyzed using sequencing techniques.

Future research using this capsule would enable more accurate and efficient data acquisition, improving our understanding of the effect of the gut microbiota on human health.