COMSOL CONFERENCE 2016 BOSTON

Fluid Flow in the Human Small Intestine

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Introduction:

- Digestion is the process of breaking down food into smaller components which can be easily absorbed in the intestinal tract.
- Research in human digestion is limited due to the complex multistage process of digestion and technical difficulties in obtaining real time data.
- The possibility of numerically analyzing the fluid dynamics of food in the human gastrointestinal tract can enhance the understanding of the human digestive process and this could be useful for the food and health sectors in predicting the bio-availability of nutrients.

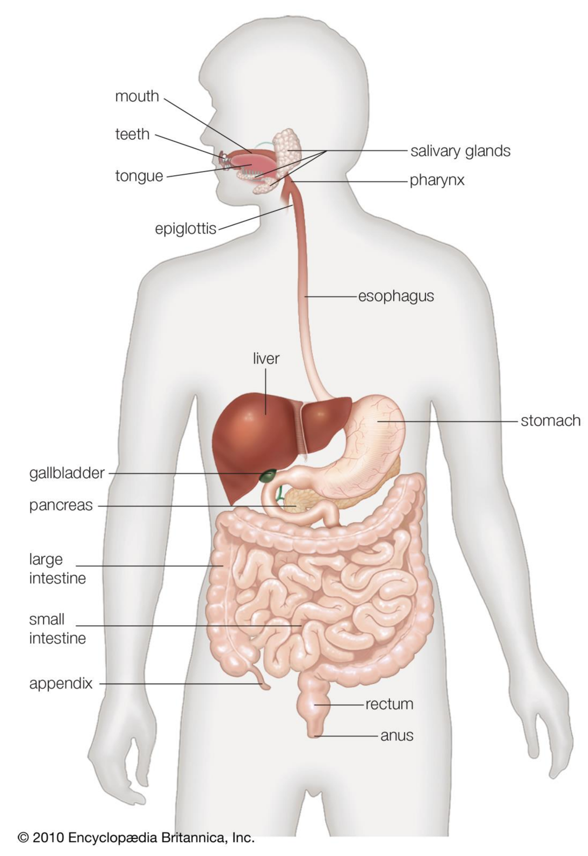

Figure 1: The human digestive system

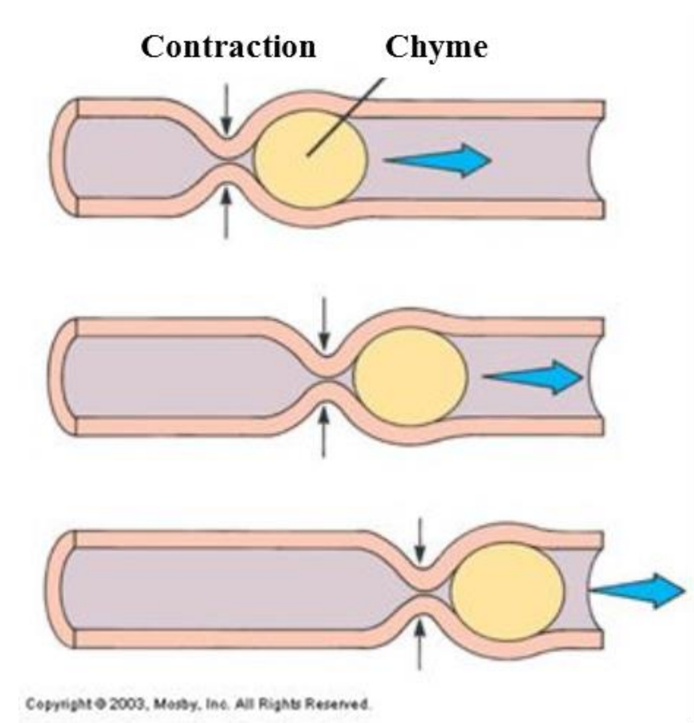

Figure 2: Peristaltic wave motion in the small intestine

- Based on previous research, it could be inferred that the viscosity of the gastrointestinal content can affect its residence time in the digestive tract and the amount of nutrients available for absorption[1].
- **Aim of this research:** To numerically predict the glucose absorption rate in the small intestine as a function of the viscosity of a starch-based food system.
- This poster focuses on **Step 1:** To develop a fluid flow numerical model approximating small intestinal geometry and motility (peristalsis).

Computational methods:

- A 2D axisymmetrical fluid flow model was developed for a small section of the small intestine (5 cm long and 1.1 cm diameter). Properties of water were used to predict the fluid flow.
- The basic geometry and motility parameters required to develop this model were obtained from a study performed by Ohkubo et al., (2013)[2]. This study assessed the small intestinal motility in healthy human volunteers using an MRI technique.

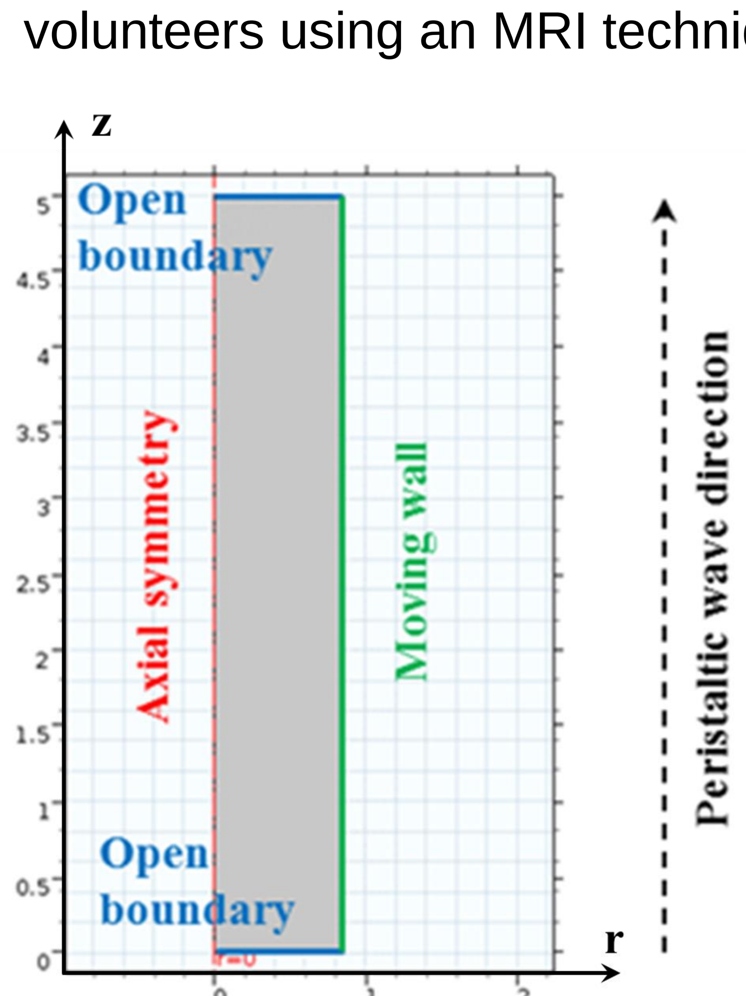

Figure 3: Boundary conditions of the 2-D axisymmetric geometry

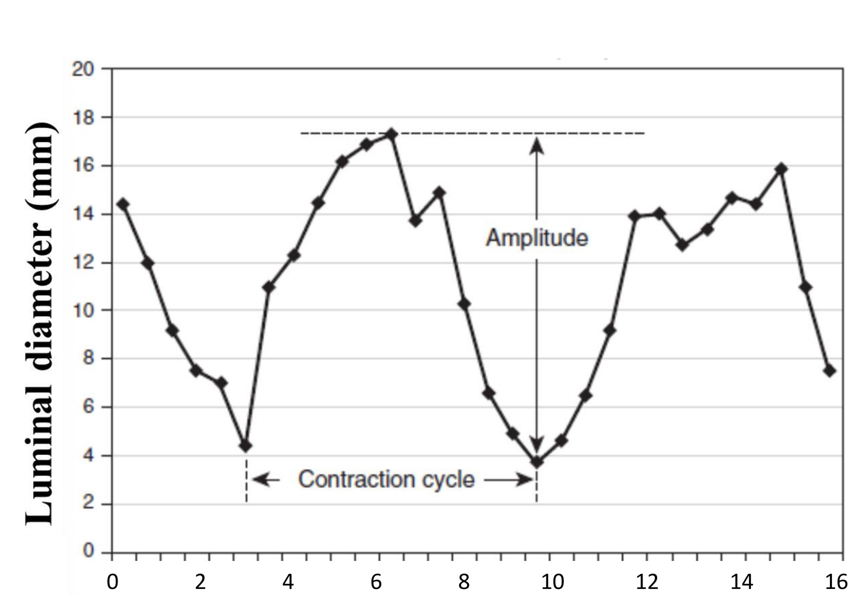

Figure 4: A typical intestinal contraction (Ohkubo et al., 2013)

- The model was developed in COMSOL Multiphysics® using *laminar flow* physics (the continuity equation and the Navier-Stokes equation) and the gut motility was incorporated using the *moving mesh* physics.

Results:

- In the Figure 5, the colors represent velocity levels, blue being the lowest and red being the highest.
- The fluid flow was observed in the direction of the peristaltic wave as indicated by small black arrows. Localized flow reversal was observed during the initiation of the peristaltic wave.
- The numerically predicted flow field was qualitatively confirmed with the results reported by Hari et al. (2012)[3].

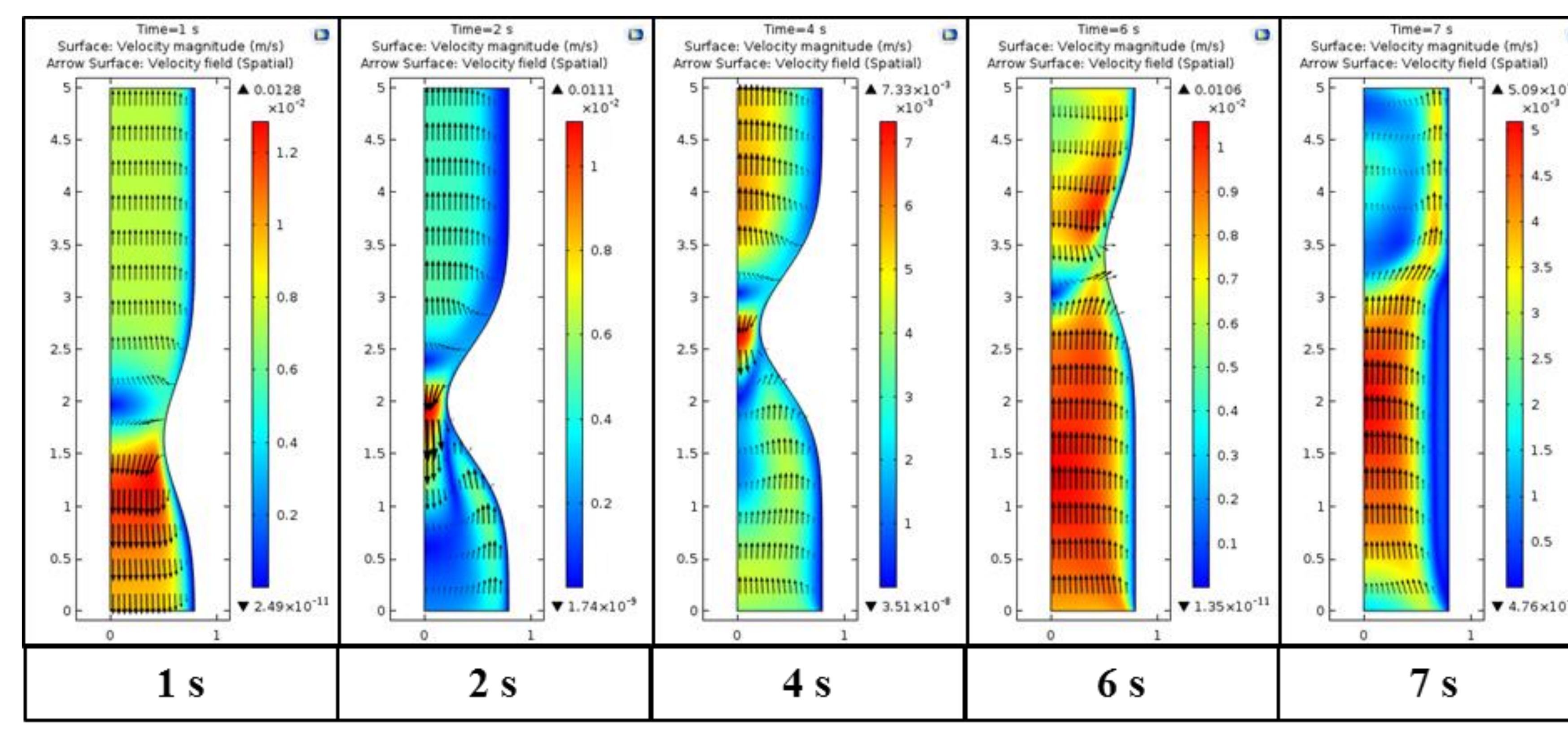

Figure 5: Velocity profile in a section of the small intestine induced by a peristaltic wave at different time intervals, predicted by COMSOL Multiphysics®

- **Conclusion:** A numerical fluid flow model was successfully developed to predict the velocity profile induced by a peristaltic wave, in a small section of small intestine.

Future work:

- **Step 1:** The flow model should be further developed to simulate the fluid flow in the entire length of the small intestine with multiple peristaltic waves and with fluid properties (density and viscosity) closer to real-time-food values.
- **Step 2:** To incorporate reaction and diffusion physics to the fluid flow numerical model and predict glucose absorption rate as a function of the viscosity of the starch-based food system.

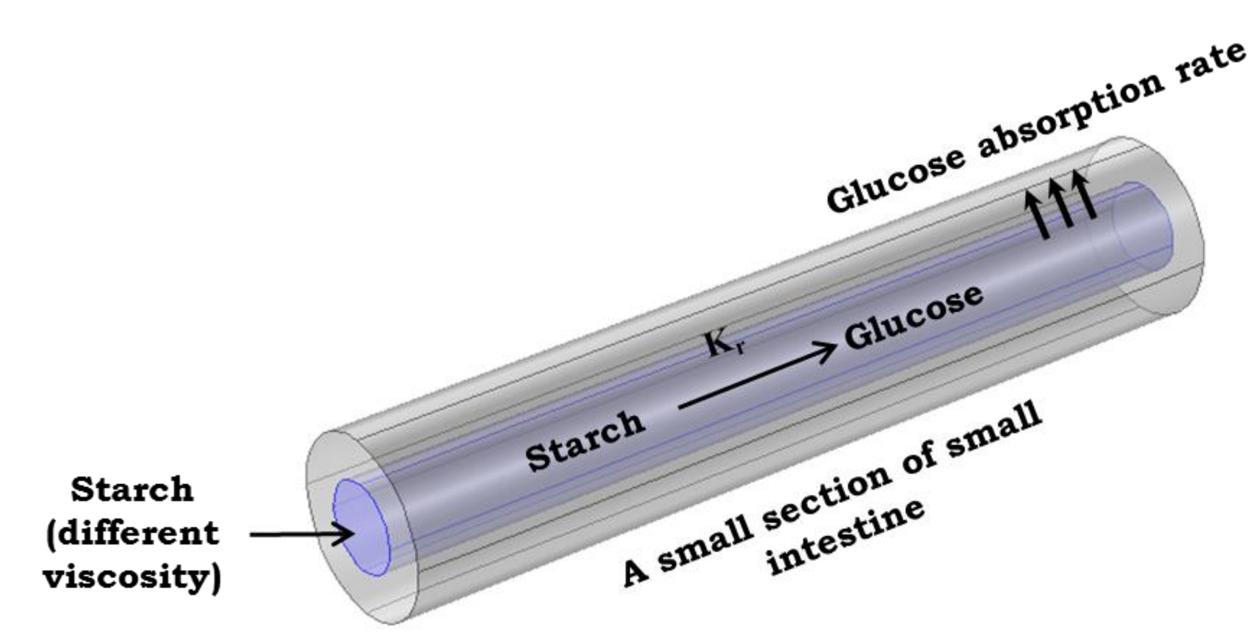

Figure 6: Future plan to incorporate reaction and diffusion physics

- **Step 3:** To validate the numerically predicted glucose absorption rate with experimentally obtained results from an *in vitro* gastrointestinal model (the TIM-1 system), for the accurate simulation of the human digestive process.

References:

1. Tharakan, A. et al., Mass transfer and nutrient absorption in a simulated model of small intestine, Journal of Food Science, 75(6), 339-346, (2010).
2. Ohkubo, H. et al., Assessment of small bowel motility in patients with chronic intestinal pseudo-obstruction using cine-MRI, The American Journal of Gastroenterology, 108(7), 1130-1139, (2013).
3. Hari, B. et al., Computational modelling and simulation of the human duodenum. Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan, (2012).