Effect of Viscosity of Food on Digestion and Nutrient Absorption in the Human Small Intestine

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Abstract

Digestion is the process of breaking down food into smaller components, by mechanical and enzymatic action in the digestive tract, so that the smaller nutrient molecules can be more easily absorbed in the intestinal tract. To study and analyze the human digestive process, different methodologies have been used in the past. In general, in vivo feeding studies with humans provide the most accurate results. However, these procedures are time-consuming and expensive (1). The accuracy of in vitro digestive studies are incomparable to that of an in vivo study and compromise is needed between accuracy of the results and effort in developing/operating the in vitro model (2). The ability of numerical models to advance gastrointestinal research is promising. The successful development of this approach demands a combinatory effort across disciplines (including mathematics, medicine, science, and engineering) (3). The possibility of numerically analyzing the 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 modeling the bio-availability of nutrients and pharmaceuticals.

Based on previous research related to human digestion our hypothesis is that the rate of digestion and nutrient absorption in the small intestine is inversely proportional to the food viscosity (3, 4). The two objectives of this study are (i) to develop a fluid flow numerical model mimicking small intestinal geometry and intestinal motility and (ii) to incorporate diffusion and reaction physics to the fluid flow model and predict the nutrient absorption rate as a function of intestinal content viscosity. To perform numerical simulation, the COMSOL Multiphysics® software is being used. A two-dimensional axisymmetric model of the entire section of the small intestine (diameter: 3 cm and length: 5 m) will be developed to simulate the fluid flow (based on the Navier-Stokes equations) due to peristaltic waves traveling at approximately 1 cm/s speed5. In the COMSOL Multiphysics® software, the laminar flow and moving mesh functionality was used to simulate the fluid flow. Based on the gut motility parameters obtained from the literature (5, 6), the peristaltic wave condition is imposed on the walls of the geometry. The preliminary result of velocity profile induced by a peristaltic wave in a section of small intestine is shown in Figure 1. In the figure, the colors represent velocity levels, blue being the lowest and red being the highest.

In future, this numerical model will be improved by simulating the entire geometry of the small intestine and by introducing multiple peristaltic waves throughout the geometry. To that fluid flow model, the Transport of diluted species physics would be incorporated to

predict the effect of intestinal content viscosity on the digestion of a defined food system and the diffusion rate of digested nutrients through the walls. Numerically predicted results would be experimentally validated with a study that was carried separately with an in vitro digestive model. Based on experimental validation, the numerical model will be improved for accurate prediction of the human digestive process.

Reference

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Figures used in the abstract

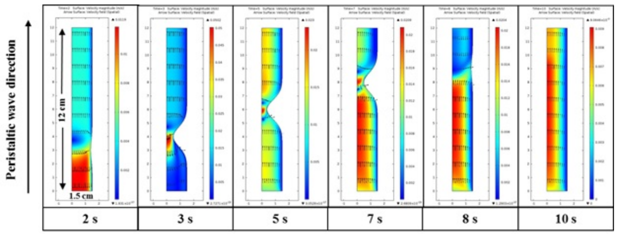

Figure 1: Velocity profile in a section of the small intestine induced by a peristaltic wave at different time intervals, predicted by COMSOL Multiphysics® software.