Dynamic gastric Model

Biorelevant Gastro-Intestinal Modelling

The Dynamic Gastric Model (DGM) is a bench-top AI-driven *in vitro* system that simulates digestion in the human stomach, allowing accurate prediction and understanding of the behaviour of foods or drug preparations during digestion in real time. The DGM has been extensively validated against human *in vivo* studies and fully replicates both the complex biochemical conditions and the array of gastric forces crucial for the prediction of the bio-behaviour of API's and dosage forms for oral delivery.

The Dynamic Gastric Model supports the acceleration of drug and food development, de-risking clinical trial failure through predictive bioavailability or bioequivalence and providing a fully validated alternative to animal studies.

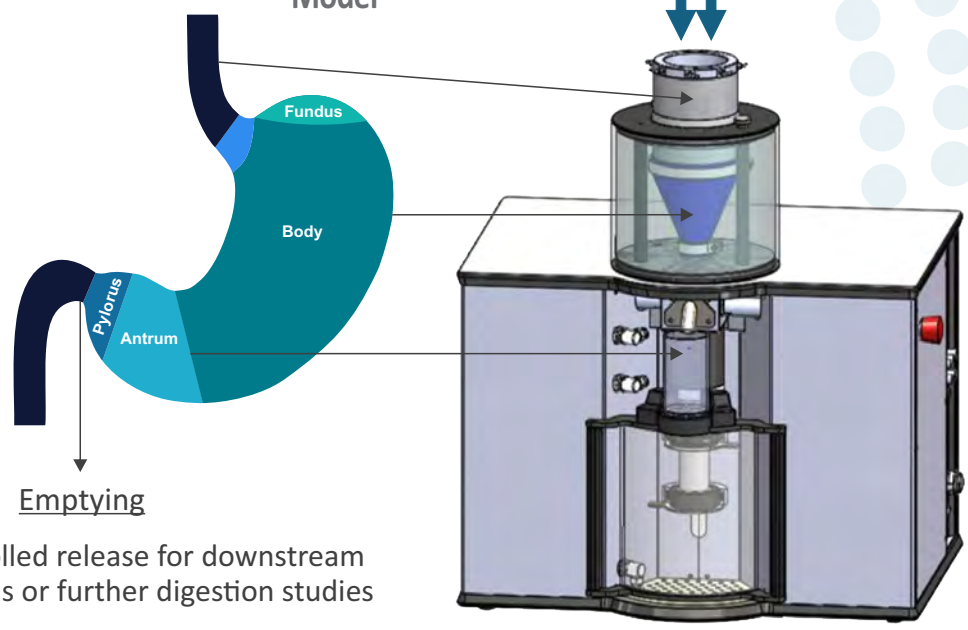
Key Features:

- Accurate replication of gastric processing parameters, representative gastric emptying and pH profiles, validated against measured *in vivo* human data
- Fed or Fasted state conditions simulated
- Automated dynamic adjustment of gastric acid and enzymes depending on food matrix
- Controllable gastric emptying and discharge, programable stomach to simulate a disease state
- Monitoring in real time and generation of detailed report throughout the digestive process such as enzyme flow rate and pH
- Emptied samples can be utilised for downstream analysis or further digestion studies

Benefits:

- The ability to investigate the digestion of both real foods and/or real pharmaceutical preparations on the laboratory bench
- A large capacity allowing full multiphase meals to be assessed, including the “FDA breakfast”
- Allows sample collection at any time point from both the main body of the stomach and on exit from the antrum, allowing real time collection and detailed analysis
- Provides a physiological, cost effective and ethical alternative to the use of animal studies, supporting the FDA Modernisation Act 2.0
- Easy to clean, with minimum down time
- Fully automated, intuitive user interface

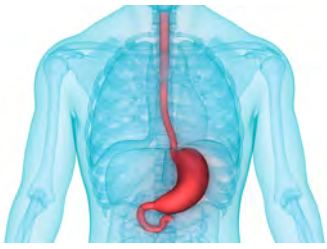
Dynamic gastric Model



Body/Fundus
- Gentle rhythmic massaging
- Inhomogeneous environment

Antrum
- High sheer forces
- Homogenization
- Contractions

Applications



1. **Food-Drug interactions**
   Assess the effect of food on the bio-performance of API and pharmaceutical dosage forms.

2. **Alcohol induced interactions**
   Determine the extent of alcohol-based interactions with modified release dosage forms. The model can be used to simulate alcohol intake regimes that are not readily evaluable in human studies.

3. **Dissolution testing**
   Evaluate biorelevant disintegration and dissolution of dosage forms. In addition, dissolution characterisation for low solubility APIs such as BCS class II and IV can be modelled.

4. **Bioequivalence**
   Assess bioequivalence and behaviour of oral formulations such as the use of enteric coating.

5. **Dosage form**
   Develop modified release dosage form and gastro-retentive dosage forms through understanding mechanical integrity and drug release.

6. **Metabolic stability**
   Study the metabolic stability of pro-drugs and gastric delivery API's.

7. **Food science**
   Assess health implications of food such as survival of allergenic proteins and determination of Glycaemic Index.

8. **Nutrition**
   Understand the nutritional effects of food after gastric digestion such as bioavailability of nutrients and the behaviour of prebiotics.

Dynamic Gastric Model (DGM) units can be purchased through Plant Bioscience Ltd (UK) and supplied to the research and development community.

For more information including references, please visit:
www.dynamicgastricmodel.com

PBL Technology

Contact:
Dr Georgina Pope | info@dynamicgastricmodel.com | Tel: +44 (0)1603 456500

Selected paper references regarding the development and application of the Dynamic Gastric Model

Pharmaceutical

Knopp MM *et al*. (2025). **Predicting the pharmacokinetics and food effect of oral drug products using the dynamic gastrointestinal model (DGM).** *European Journal of Pharmaceutics and Biopharmaceutics*; 212:114723. https://doi.org/10.1016/j.ejpb.2025.114723

Knopp MM *et al*. (2025). **Evaluating the gastric integrity of Capsugel® Enprotect® capsules in fasted and fed state using the Dynamic Gastric Model.** *5th European Conference of* Pharmaceutics [2025 Conference Poster].

Knopp MM *et al*. (2023). **Combining the Dynamic Gastric Model (DGM) with the Biorelevant Gastrointestinal Transfer (BioGIT) System to Evaluate the Performance of Three Nurofen® Ibuprofen Products.** *AAPS PharmSci 360* [2023 Conference Poster]

Pultz IS *et al. (*2021). **Gluten Degradation, Pharmacokinetics, Safety, and Tolerability of TAK-062, an Engineered Enzyme to Treat Celiac Disease.** *Gastroenterology*; 161(1): 81-93.e3. https://doi.org/10.1053/j.gastro.2021.03.019

In this study, computationally designed endopeptidase TAK-062 was tested in a phase I dose escalation study in healthy participants and patients with Celiac disease (CeD). Gluten degradation was assessed in vitro using the Dynamic Gastric Model. Results demonstrate that TAK-062 is well tolerated and potently degrades gluten in vitro *(> 99% degraded within 10 minutes).*

Butler J *et al.* (2019). ***In vitro* models for the prediction of *in vivo* performance of oral dosage forms: Recent progress from partnership through the IMI OrBiTo collaboration.** *Eur J Pharm Biopharm*; 136: 70-83. https://doi.org/10.1016/j.ejpb.2018.12.010

Chessa S *et al.* (2014). **Application of the Dynamic Gastric Model to evaluate the effect of food on the drug release characteristics of a hydrophilic matrix formulation.** *Int J Pharm*; 466(1-2): 359-367. https://doi.org/10.1016/j.ijpharm.2014.03.031

This study assessed the suitability of the Dynamic Gastric Model for studying food effect on a hydrophilic matrix formulation in comparison with the conventional USP dissolution methodology. Dissolution data measured with the compendial methods indicated the HCTZ tablet was not sensitive to food-effect, whereas the Dynamic Gastric Model detected changes in physical properties and drug release performance.

Vardakou M *et al.* (2011). **Predicting the human *in vivo* performance of different oral capsule shell types using a novel *in vitro* dynamic gastric model.** *Int J Pharm*; 419(1-2): 192-199. https://doi.org/10.1016/j.ijpharm.2011.07.046

This study compared the use of the Dynamic Gastric Model with the USP dissolution apparatus to compare different capsule formulations of paracetamol. Results were then compared with in vivo gamma scintigraphy human data and gastric emptying profiles. Rupture times of all capsules and gastric emptying profiles measured by the Dynamic Gastric Model in fasted state aligned with in vivo gamma scintigraphy and plasma profiling.

Vardakou M *et al.* (2011). **Achieving Antral Grinding Forces in Biorelevant *In Vitro* Models: Comparing the USP Dissolution Apparatus II and the Dynamic Gastric Model with Human *In Vivo* Data.** *AAPS PharmSciTech*; 12: 620-626. https://doi.org/10.1208/s12249-011-9616-z

This study assessed grinding forces of the Dynamic Gastric Model and Dissolution Apparatus USP-II with the breakdown of agar gel beads. Result suggested the Dynamic Gastric Model can simulate the gastric forces, while the Dissolution Apparatus USP-II failed to produce breaking forces.

Mercuri A *et al.* (2011). **The Effect of Composition and Gastric Conditions on the Self-Emulsification Process of Ibuprofen-Loaded Self-Emulsifying Drug Delivery Systems: A Microscopic and Dynamic Gastric Model Study.** *Pharm Res*; 28: 1540-1551. https://doi.org/10.1007/s11095-011-0387-8

This study investigated the link between formulation of self-emulsifying drug delivery systems (SEDDS) and the emulsification process in the human stomach using the Dynamic Gastric Model and the USP Dissolution Apparatus II. Samples from the Dynamic Gastric Model showed particle size remained broadly similar for both the drug and placebo. Results from the USP show a larger droplet size compared to the Dynamic Gastric Model, suggesting the mechanical agitation is important in determining size.

Mercuri A *et al.* (2009). **Assessing drug release and dissolution in the stomach by means of Dynamic Gastric Model: a biorelevant approach.** New Scientists Session, *J Pharm Pharmacol*; 61(1): A5-A7. https://academic.oup.com/jpp/article-abstract/61/Supplement_1/A5/6135917?redirectedFrom=fulltext

Mercuri A *et al.* (2008). **Dynamic gastric model (DGM): a novel *in vitro* apparatus to assess the impact of gastric digestion on the droplet size of self-emulsifying drug-delivery systems**. Short Papers in Pharmaceutics, *J Pharm Pharmacol*; 60 Supplement 1: A-2. https://doi.org/10.1211/002235708785623354

Food and Nutrition

Salt LJ *et al.* (2023). **Mechanisms of interesterified fat digestibility in a muffin matrix using a dynamic gastric model.** *Food & Function*; *14*(22): 10232-10239. https://doi.org/10.1039/d3fo02963h

Here, the authors characterised fat emptying from the gastric phase for interesterified (IE) and non-interesterified (non-IE) hard fats and rapeseed oil, using the Dynamic Gastric Model. They found that IE and non-IE fats remained solid and bound strongly to the muffin matrix, leading to delayed gastric emptying. In contrast, rapeseed oil separated as liquid droplets. Lipolysis rates were similar between IE and non-IE fats, while rapeseed oil showed slower lipolysis due to long-chain polyunsaturated fatty acids (PUFAs). Overall, digestibility was determined more by fat–matrix interactions and physical behaviour than by interesterification itself.

Mills CE *et al.* (2021). **Palmitic acid–rich oils with and without interesterification lower postprandial lipemia and increase atherogenic lipoproteins compared with a MUFA-rich oil: A randomized controlled trial.** *Am J Clin Nutr*; 113(5):1221-1231. https://doi.org/10.1093/ajcn/nqaa413

Edwards CH *et al.* (2021). **Structure-function studies of chickpea and durum wheat uncover mechanisms by which cell wall properties influence starch bioaccessibility.** *Nat Food*; 2: 118-126. https://doi.org/10.1038/s43016-021-00230-y

Mandalari G *et al.* (2018). **Understanding the Effect of Particle Size and Processing on Almond Lipid Bioaccessibility through Microstructural Analysis: From Mastication to Faecal Collection.** *Nutrients*; 10(2): 213. https://doi.org/10.3390/nu10020213

Grassby T *et al.* (2017). ***In vitro* and *in vivo* modeling of lipid bioaccessibility and digestion from almond muffins: The importance of the cell-wall barrier mechanism.** *Journal of Functional Foods*; 37: 263-271. https://doi.org/10.1016/j.jff.2017.07.046

Mandalari G *et al.* (2018 Epub 2016). ***Durum* wheat particle size affects starch and protein digestion in vitro.** *Eur J Nutr*; 57(1): 319-325. https://doi.org/10.1007/s00394-016-1321-y

Mandalari G *et al.* (2016). **The effect of sun-dried raisins (*Vitis vinifera* L.) on the *in vitro* composition of the gut microbiota.** *Food & Function*; 7(9): 4048-4060. https://doi.org/10.1039/c6fo01137c

Mason LM *et al.* (2016). **Use of the Dynamic Gastric Model as a tool for investigating fed and fasted sensitivities of low polymer content hydrophilic matrix formulations.** *International Journal of Pharmaceutics*; 510(1): 210-220. https://doi.org/10.1016/j.ijpharm.2016.06.034

This study assessed how the polymer content of hydrophilic matrices influence drug release (namely caffeine) in both fasted and fed environment in vitro using the DGM. The findings highlight that drug release in the fed state is notably influenced by the presence of a high fat meal, resulting in an initial delay in drug release. In both fasted and fed states, erosion appears to be the dominant release mechanism, in contrast to USP testing where diffusion played a more crucial role.

Thuenemann EC *et al.* (2015). **Dynamic Gastric Model (DGM). In: Verhoeckx, K., *et al.* The Impact of Food Bioactives on Health: *in vitro* and *ex vivo* models**. *Springer, Cham*; Chapter 6: 47-59. https://doi.org/10.1007/978-3-319-16104-4_6

Rodes L *et al.* (2014). **Enrichment of *Bifidobacterium longum subsp. infantis* ATCC 15697 within the human gut microbiota using alginate-poly-L-lysine-alginate microencapsulation oral delivery system: an *in vitro* analysis using a computer-controlled dynamic human gastrointestinal model.** *J Microencapsul*; 31(3): 230-238. https://doi.org/10.3109/02652048.2013.834990

Zhang Q *et al.* (2014). **Differential Digestion of Human Milk Proteins in a Simulated Stomach Model.** *J Proteome Res*; 13(2): 1055-1064. https://doi.org/10.1021/pr401051u

Ballance S *et al.* (2013). **Evaluation of gastric processing and duodenal digestion of starch in six cereal meals on the associated glycaemic response using an adult fasted dynamic gastric model.** *Eur J Nutr*; 52(2): 799-812. https://doi.org/10.1007/s00394-012-0386-5

This study investigated cereal starch digestion and glycaemic response using the Dynamic gastric Model. A range of grains were processed and fed into the Dynamic Gastric Model with water. Results found no significant difference in glycaemic index values from this in vitro model compared to in vivo data.

Mandalari G *et al.* (2013)**. Bioaccessibility of pistachio polyphenols, xanthophylls, and tocopherols during simulated human digestion.** *Nutrition*; 29(1): 338-344. https://doi.org/10.1016/j.nut.2012.08.004

This study investigated polyphenol, xanthophylls (lutein), and tocopherols from various preparations of pistachios during digestion with the Dynamic Gastric Model. Raw pistachios and roasted, salted pistachios were masticated and fed into the Dynamic Gastric Model for digestion. Samples were then processed with duodenal digestion and followed by analysis. Results showed the bioactives become accessible in the stomach, increasing the potential for absorption in the intestines.

Pitino I *et al.* (2011). **Survival of *Lactobacillus rhamnosus* strains inoculated in cheese matrix during simulated human digestion.** *Food Microbiology*; 31(1): 57-63. https://doi.org/10.1016/j.fm.2012.02.013

This study used the Dynamic Gastric Model to investigate the survival of probiotic bacteria, previously isolated from Pecorino cheese, in the gastrointestinal tract. Strains of Lactobacillus were fed to the Dynamic Gastric Model within a model cheese, and monitored for survival. The Lactobacillus strains showed good survival after gastric digestions, with cheese working as an effective delivery system.

Lo Curto A *et al.* (2011). **Survival of probiotic lactobacilli in the upper gastrointestinal tract using an *in vitro* gastric model of digestion.** *Food Microbiology*; 28(7): 1359-1366. https://doi.org/10.1016/j.fm.2011.06.007

This study investigated the survival of probiotic Lactobacillus strains in the upper gastrointestinal tract, using the Dynamic Gastric Model. The model was fed the bacteria resuspended in water or milk. Results showed survival of the probiotic strains after in vitro digestion, with a higher survival in milk compared to water.

Pitino I *et al.* (2010). **Survival of *Lactobacillus rhamnosus* strains in the upper gastrointestinal tract.** *Food Microbiology*; 27(8): 1121-1127. https://doi.org/10.1016/j.fm.2010.07.019

Mandalari G *et al.* (2008). **Potential Prebiotic Properties of Almond (*Amygdalus communis* L.) Seeds.** *Appl Environ Microbiol*; 74(14): 4264-4270. https://doi.org/10.1128/AEM.00739-08

Marciani LG *et al.* (2007). **Enhancement of intragastric acid stability of a fat emulsion meal delays gastric emptying and increases cholecystokinin release and gallbladder contraction.** *Am J Physiol Gastrointest Liver Physiol*; 292(6): G1607-1613. https://doi.org/10.1152/ajpgi.00452.2006

Development of the Model

Wickham MJS *et al.* (2012). **The Design, Operation, and Application of a Dynamic Gastric Model.** *Dissolution Technologies*; 19(3): 15-22. https://doi.org/10.14227/DT190312P15

Burnett GR *et al.* (2002). **Interaction between protein allergens and model gastric emulsions.** *Biochem Soc Trans*; 30(6): 916-918. https://doi.org/10.1042/bst0300916

Marciani LG *et al.* (2001). **Effect of meal viscosity and nutrients on satiety, intragastric dilution, and emptying assessed by MRI.** *Am J Physiol Gastrointest Liver Physiol*; 280(6): G1227-G1233. https://doi.org/10.1152/ajpgi.2001.280.6.g1227