MRI and MRS measurements of intragastric fat spatial distribution

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Background: Gastrointestinal (GI) function and satiety are strongly influenced by intragastric distribution of fat. Early nuclear medicine studies showed the rate of emptying of water and fat from the stomach depended on whether the fat was incorporated within the food matrix [1]. However such studies were limited by radiation dose and did not investigate the intragastric behaviour of oil-in-water emulsions, which are commonly used in food products. MRI allows fat and water components to be imaged separately. We have recently shown that acid stable emulsions stimulate greater cholecystokinin release, delay gastric emptying and increase satiety compared to acid unstable emulsions in which the fat layer empties after the aqueous phase [2-3]. Proton spectroscopy (MRS) is widely used to determine the fat/water ratio of a sample; multi-echo DIXON (mDIXON) [4] can measure fat fraction at a much higher spatial resolution but the results may not be so quantitative. This initial study aims to compare MRS and mDIXON fat fraction estimates *in vivo* to determine the effect of fat microstructure on GI handling of emulsion meals.

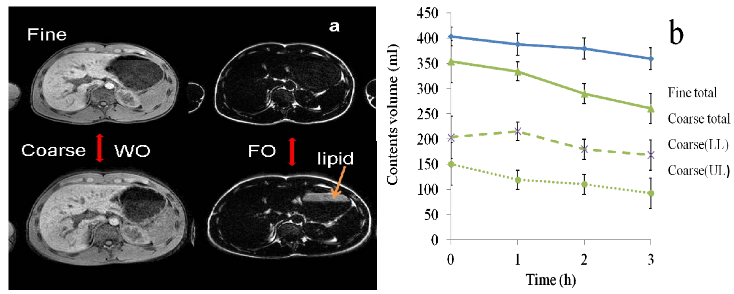

Figure. 1 (a) mDIXON images showing floating lipid layer in the fat only (FO) images of the coarse emulsion (black on the water only (WO) image). (b) Gastric emptying curves of total gastric volume and floating (UL) and sunk (LL) subvolumes for coarse emulsion

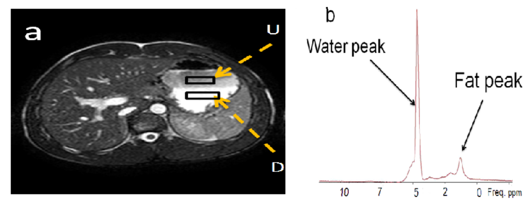

Figure 2 **(a)** bTFE images showing layering and MRS Voxels **(b)** typical spectrum of gastric contents.

Methods: **Meal:** Two fat emulsions were prepared: coarse and fine (mean droplet diameters ~0.4 µm and ~8 µm). Both contained 79% water, 20% sunflower oil, 1% emulsifier, sweetener and flavouring. **Subjects:** The study was approved by the local Ethics Committee. 6 healthy male volunteers (18-35 y.o) with no history of GI disease attended on 2 mornings having fasted overnight. Initial baseline scans were acquired and then the volunteer consumed 300g of one of the meals (60g fat in total) in random order. **MRI and MRS:** Data were acquired hourly for 3 hours using a Philips 1.5T Achieva scanner and 16-channel body coil. bTFE [gastric volumes and planning MRS voxel] 40 axial slices acquired in a 13s breath-hold, FA=80^{o}, TR/TE= 2.8/1.4ms, in plane resolution 1.56x1.56mm, SL 7mm, SENSE 2.0. MRS [intra-gastric fat fraction] STEAM (90^{o}-90^{o}-90^{o}), TR/TE=4000/9ms, 2 dummies, bandwidth 1000 Hz, 512 samples, 4 repeats in 24 s. Acquired twice, in the upper and lower regions of the gastric lumen. Transverse mDIXON [intra-gastric fat fraction] 3D TFE double echo, FA=15, TE1/TE2/TR= 1.8/4.0/5.4 ms, SL=3 mm, in-plane resolution 1.49x1.95 mm^2, NSA=1. Data were reconstructed to water-only and fat-only images [4] (fig 1). Each sequence was acquired in a breath hold. Manual regions of interest were drawn to measure gastric volumes. The MRS data (fig 2) was analysed with in-house software. mDIXON fat fraction was calibrated against *in vitro* samples of the same emulsions at different levels of dilution and temperature.

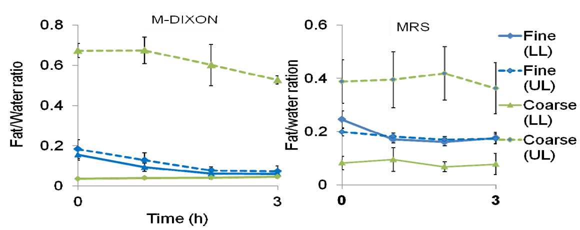

Figure 3 Fat water fraction measured in the fine and coarse emulsion for upper and lower layers (UL & LL) for and mDIXON (right) the MRS (left) sequences.

Results: The images and quantitative data showed that the coarse emulsion immediately separated in the GI tract, into a high fat content floating phase and a low fat content sunk phase. The fine emulsion remained stable. At t=0 the MRS measures of total fat content of the stomach and the average fat fraction of the emulsion (fig 3) agreed better with fat in ingested meal (assuming only small meal dilution at t=0) than mDIXON measures. Gastric emptying of the fine emulsion was significantly delayed compared to the coarse emulsion with p=0.03 (fig 1b) although the differential volume measurements showed that both the upper and lower layers of the gastric contents emptied steadily and MRS showed the fat content of the upper layer gradually reduced over 3 hours (fig 3). Interestingly the net rate of emptying of fat (calculated from volumes and MRS fat fractions) was similar for both meals (fig.4).

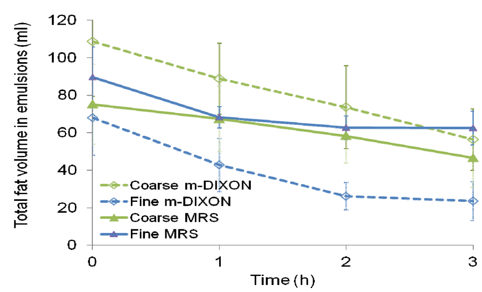

Figure 4: Total fat in gastric contents estimated for both emulsions and by MRS and mDIXON.

Discussion: Despite the differences in the physicochemical behaviour of these meals in the gastric lumen, and differences in total gastric emptying rates, the net rate of fat emptying between them was remarkably similar. The mechanisms for the dilution and emptying of the high fat, floating layer need to be investigated. mDIXON provided good information on spatial distribution of fat allowing volumes of different phases to be measured, but although the profiles of fat emptying for mDIXON and MRS were similar, the MRS data gave more plausible results at t=0 suggesting that the *in vitro* calibration used for mDIXON was not valid *in vivo*, probably due to shimming effects or changes in relaxation times. SUPPORTED BY UNILEVER CASE AWARD **References:** [1] Cunningham KM, et al. J Nucl Med. 1991 May;32:878-81. [2] Marciani L, et al. Br J Nutr. 2009 Mar 28;101:919-28. [3] Marciani L, et al. Am J Physiol. 2007;292:G1607-G13. [4] Eggers H, et al. Magn Reson Med. 2011, 65:96-107.